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ENVIRONMENTAL CHARGING TESTS OF SPACECRAFT THERMAL CONTROL LOUVERS

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16. Abstract

The NASA/USAF program on the Environmental Charging of Spacecraft Surfaces consists, in part, of experimental evaluation of material response to the environmental charged particle flux. A flight-type spacecraft thermal control louver assembly has been tested in an electron flux. The louver blade surface potential, the louver assembly currents, and the relatively high number of discharges observed in the electron environment are self-consistent results. The unexpected result of this testing was the flutter observed when the louvers were closed. The flutter is about 1 to 2 Hz in frequency and is probably electrostatically induced.

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INTRODUCTION

E-8927

Geosynchronous satellites have experienced anomalous electronic switching in the midnight to dawn region of their orbits (ref. 1). Environmental measurements have shown that energies of transient particle fluxes are higher than expected in this region (ref. 2 to 4). Spacecraft anomalous behavior correlates well with the occurrence of geomagnetic substorms (ref. 5 and 6). Differential charging of spacecraft surfaces can occur (ref. 7) and breakdown of charged dielectric materials can follow. Differential charging can result in unwanted fields. Breakdown can result in electromagnetic interference, degradation of thermal control surfaces, and surface contamination (ref. 8).

An experimental effort to evaluate the behavior of materials in simulation of the environmental charged particle flux is a part of the NASA/Air Force spacecraft charging investigation program (ref. 9). This report is one of a series of test reports on the behavior of thermal control materials (ref. 10 and 11) and presents the results of tests performed on thermal control louvers of the type to be used on the Global Positioning System (GPS) spacecraft. Testing was in response to a request by the Rockwell International Corporation through the Air Force; the louvers were supplied by the Rockwell International Corporation. The GPS spacecraft will not be at synchronous orbit; however, the environment at their nominal 20,352 kilometer orbit is sufficiently unknown to justify undertaking the testing reported herein.

APPARATUS AND PROCEDURE

Specimen Tested

The test specimen is shown in figure 1. The test specimen is the GPS Qualification Thermal Louver Assembly (Part Number: 302-0100-01) mounted on an aluminum handling frame 40cm x 46cm frontal area. The louver blades are thin, highly polished aluminum and are mounted in polymeric bearings mounted on a polished aluminum frame. The blades

are actuated by bimetallic sensors located in the center housing. This housing is thermally insulated from the exterior environment. When the spacecraft interior temperature rises, the sensors expand, the blades open, and more heat is radiated through the louver assembly to space. The louvers are fully closed below 2°C and fully open above 20°C.

Facility

The test facility is shown schematically in figure 2. Testing was performed in a 1.8m diameter by 1.8m long vacuum chamber. The vacuum chamber is oil-diffusion-pumped and pressure is maintained between 8.0×10^{-6} and 1.3×10^{-5} Pa. The grounded metallic thermal control shroud formed the boundary condition for all tests. A divergent electron beam was generated from a hot wire filament by means of a spherical segment accelerating screen. The filament was biased to the desired voltage and the accelerating screen kept at ground potential. The beam from this source produced the typical current density profile shown in figure 3. The test specimen was located 1m from the electron source on the source (and chamber) centerline. The 15cm diameter loop antenna signal was fed to an amplitude discrimination circuit that counted all pulses greater than 0.5, 2.5, and 5 volts. The substrate of the specimen was grounded through an electrometer to measure the specimen current to ground. The specimen current could also be shorted to ground and a current probe and oscilloscope used to obtain the transient current pulses from discharges. A surface voltage probe was swept in an arc intercepting the centerline of the specimen and was 0.5cm from the face of the specimen. The probe uses an electric field sensing-null balance technique to measure the specimen surface potential. The facility was designed for specimens nominally 30cm by 30cm in size.

Test Procedure

The behavior of the louvers in simulations of the environmental charged particle flux was determined by performing a survey test at three electron flux levels. The louvers were bombarded by electrons accelerated through potentials of 5, 8, 10, 12, 14, 16, 18, and 20kV at electron beam current densities of 0.5, 1, and 3 nA/cm^2. They were subjected to each condition for 20 minutes to insure equilibrium. The current to ground and the number of discharges were recorded during each condition. The surface voltage was measured after equilibrium was observed at each condition. A complete set of surveys was run with the louvers open, at approximately 30°C, and with the louvers closed, at approximately -1°C.

RESULTS

Test results are summarized in tables 1 and 2. Table 1 contains sample current to ground as a function of incident current density and beam voltage. Also presented is the average louver surface potential for each incident current density. Table 2 contains the number of discharges counted during testing as a function of incident current density and beam voltage. The complete set of data is presented in the appendix to this report.

DISCUSSION

Surface Potential

The louver blades reached a surface potential of approximately 1.2 kilovolts during testing (see table 1). Thus, the inherent voltage stress capability of the louver assembly is at this level and greater surface potentials cannot be reached. Testing with electron beams of 5kV and greater resulted in this nominal surface potential.

Sample Current to Ground

Three observations can be made about the sample current-to-ground. First, the values in table 1 represent current-to-ground of the entire assembly; some of the beam was incident on the aluminum handling frame. The current observed, then is a combination of that from conducting and insulating structures in the incident electron beam. Second, the frontal area of the sample exceeds that of the shield normally used to cover the sample as electron beam conditions are established. The dimensions of the test facility and apparatus did not permit sample shielding. Thus, the charging of the sample was not directly observed by means of the sample current data. Third, the frontal area of the sample was large enough such that a variation in electron beam density was observed across the sample plane (see figure 3). Additionally, it has been observed that as the beam voltage is increased the electron beam becomes more concentrated. Thus, sample currents to ground are not directly proportional to the nominal incident current density. The data has been considered in the light of the foregoing observations and there appear to be no unexpected trends.

Discharges

The number of discharges obtained during testing is presented in table 2. The number of discharges were more than has been generally observed; thermal blankets for instance discharge one to two orders of magnitude

less frequently (ref. 10 and 11). However, the large number of discharges is consistent with the voltage stress capability inferred from the surface potential measurements.

Flutter

The louver assembly was visually observed during testing. When the louvers were closed, thereby maximizing the louver blade area normal to the incident electron beam, it was observed that the blades fluttered. Flutter was observed at all conditions of electron beam voltage and current density. It is probable that the flutter is electrostatic in nature: charging of the blades results in an electrostatic force causing blade motion, predominantly rotation of the blade. The frequency of the flutter varies from about 1hz to several hz, depending on beam conditions (movies have been made of this flutter).

SUMMARY OF RESULTS

Environmental charging tests have been performed on a thermal control louver assembly of the type to be used on the Global Positioning System Flight Space Vehicles. These tests have shown that the inherent voltage stress capability of the assembly permitted the louver blades to reach a surface potential of approximately 1.2 kilovolts during testing; this was measured with the louver blades closed. The sample current to ground and the number of discharges are in accordance with the observed blade surface potential.

The unexpected result of this testing was the flutter observed when the closed louvers were subjected to the electron beam. This flutter is about 1 to 2 Hz in frequency and is probably electrostatic in nature. It is suggested that the requirement for further testing and analysis should be established and pursued by the user community.

APPENDIX

This appendix contains the complete data for the louver testing. Figure A1 contains the average equilibrium specimen current as a function of beam voltage and current density. Figures A2, A3, and A4 are plots of specimen current as a function of time for the open louvers for 0.5, 1, and 3 nA/cm^2 respectively. Figures A5, A6, and A7 are plots of specimen current as a function of time for the closed louvers for 0.5, 1, and 3 nA/cm^2 respectively. Figure A8 presents the cumulative number of discharges for the closed louvers during survey testing. Figure A9 is a record of specimen current during the 15 hour extended test. Figure A10 is a record of discharges during the 15 hour extended test.

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Table 1. - Summary of Louver Surface Potential and Louver Current-to-Ground Test Data

Louver Configuration	Incident Current Density (nA/cm^2)	Surface Potential (average) (kV)	Sample Current to Ground (μA) Beam Voltage (kV)							
			5	8	10	12	14	16	18	20
Open	0.50	____[a]	0.31	0.36	0.36	0.38	0.40	0.33	0.41	0.36
	1.0	____	0.46	0.48	0.52	0.62	0.66	0.65	0.65	0.68
	3.0	____	1.3	1.7	2.0	2.0	2.2	2.5	2.4	2.3
Closed	0.50	1.2[b]	0.39	0.52	0.58	0.63	0.73	0.75	0.84	0.87
	1.0	1.2	0.54	0.91	0.93	0.98	1.0	0.98	0.97	1.0
	3.0	1.3	1.8	2.6	3.2	3.6	3.6	3.6	3.4	3.5

a. The surface potential probe was not usable with the louvers open.

b. For all beam voltage settings.

Table 2. - Summary of the Number of Discharges Obtained During Louver Testing

Louver Configuration	Incident Current Density (nA/cm^2)	Number of Discharges, Beam Voltage (kV): 5	8	10	12	14	16	18	20
Discharges over 0.5 Volts									
Closed	0.5	19,465	16,609	20,058	22,380	19,416	21,730	25,755	28,900
	1	17,667	30,208	38,700	41,475	45,270	44,826	58,053	61,700
	3	87,153	123,248	178,568	197,300	186,700	179,900	169,500	173,800
Discharges over 2 Volts									
Open[a]	0.5	0	0	0	2	10	8	0	1
	1	0	0	0	0	0	0	0	0
	3	0	0	0	0	1	3	9	40
Closed	0.5	825	3007	3604	3700	2924	2880	2704	2621
	1	2542	3503	3603	3398	3170	3577	2162	2078
	3	2817	6779	8959	9347	11074	7069	10205	13112
Discharges over 5 Volts									
Closed	0.5	134	632	467	548	16[b]	20[b]	18[b]	14[b]
	1	147	199	190	212	191	204	144	125
	3	93	294	624	565	476	325	661	546

a. Discharges with the louvers open were counted by single level, unipolar discrimination circuitry that was superseded by the multilevel, bipolar circuitry used for the louvers closed.

b. This data was obtained out of sequence and may indicate a cumulative effect.

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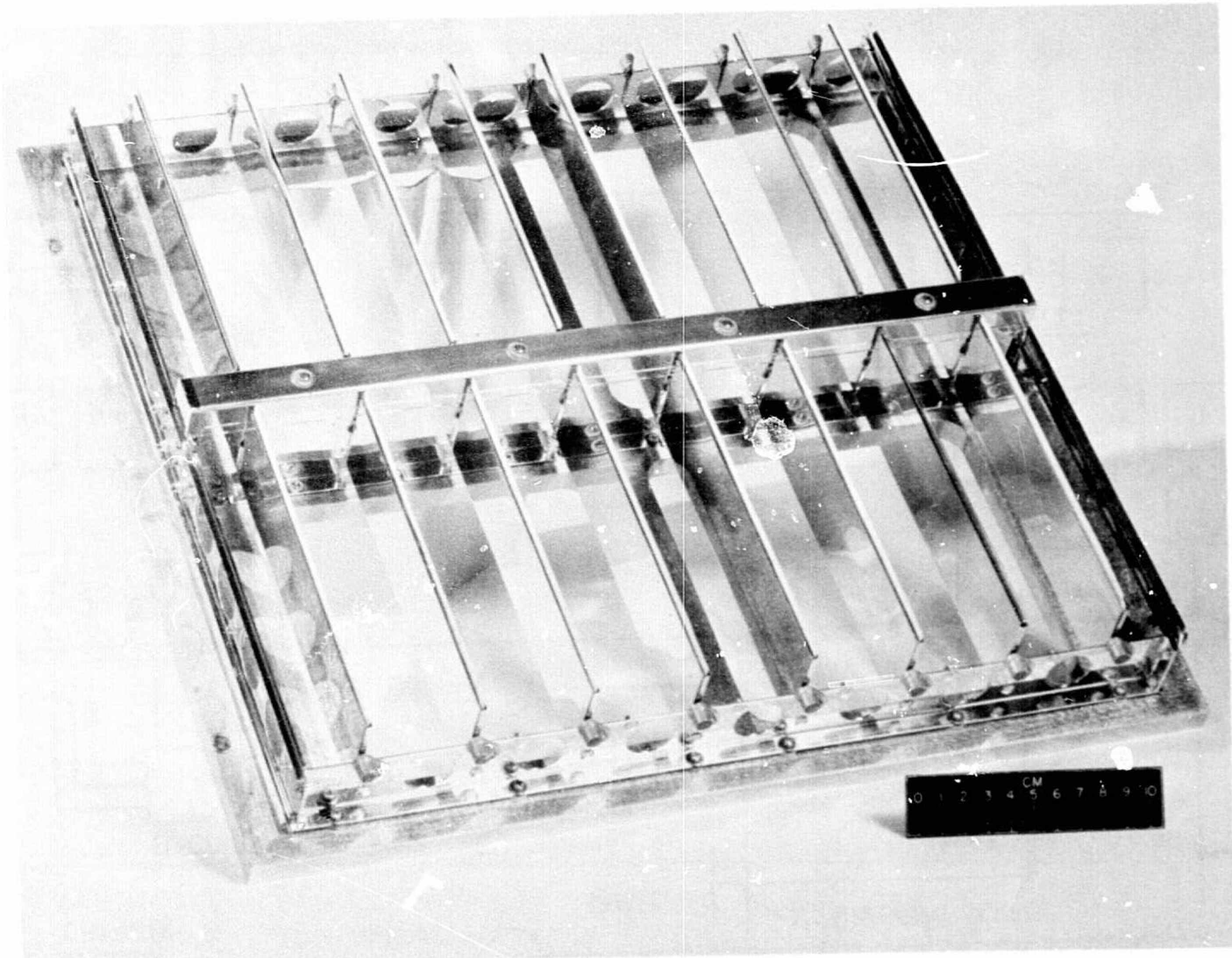


Figure 1. - Thermal louver test specimen mounted to handling frame.

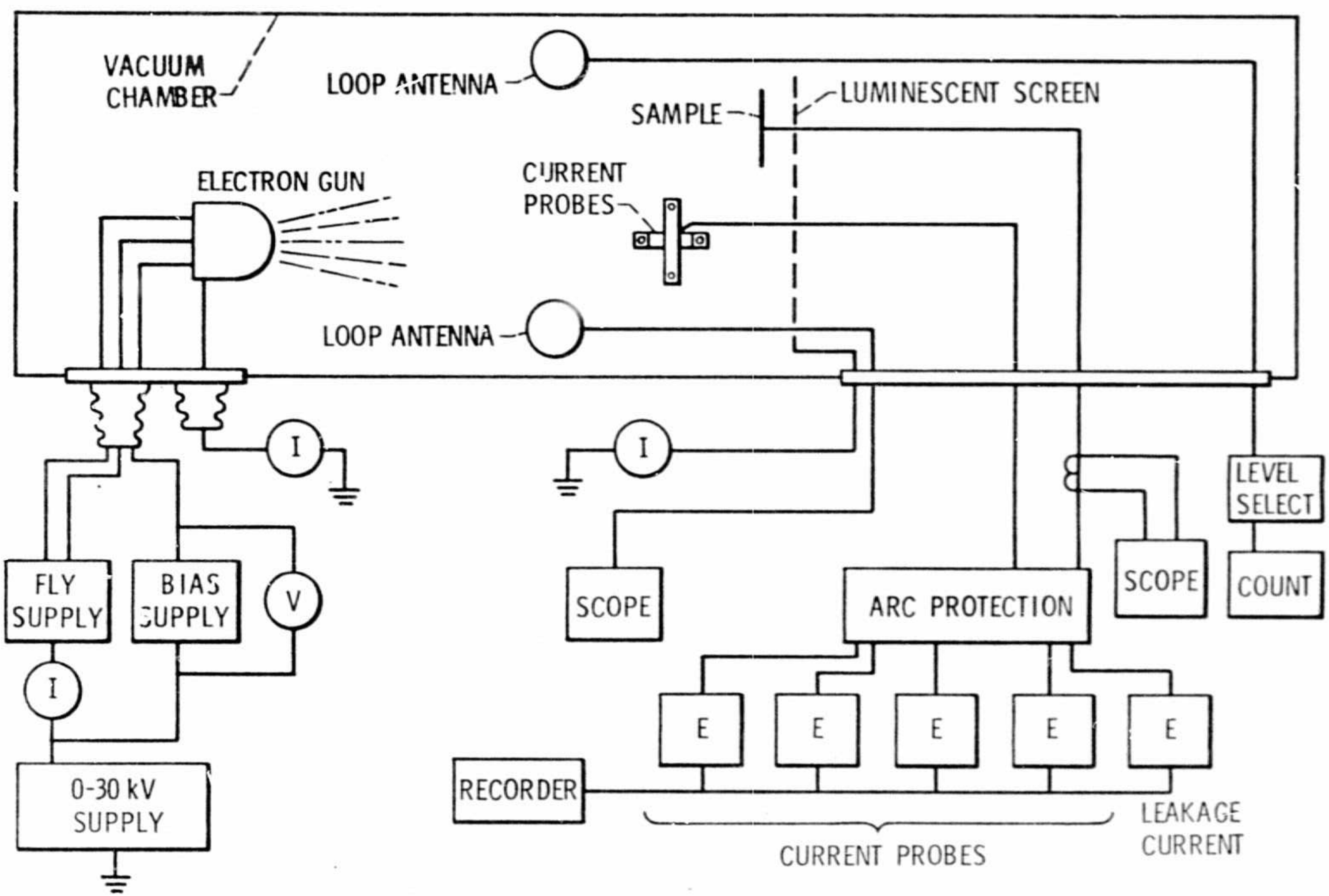


Figure 2. - Spacecraft charging test facility.

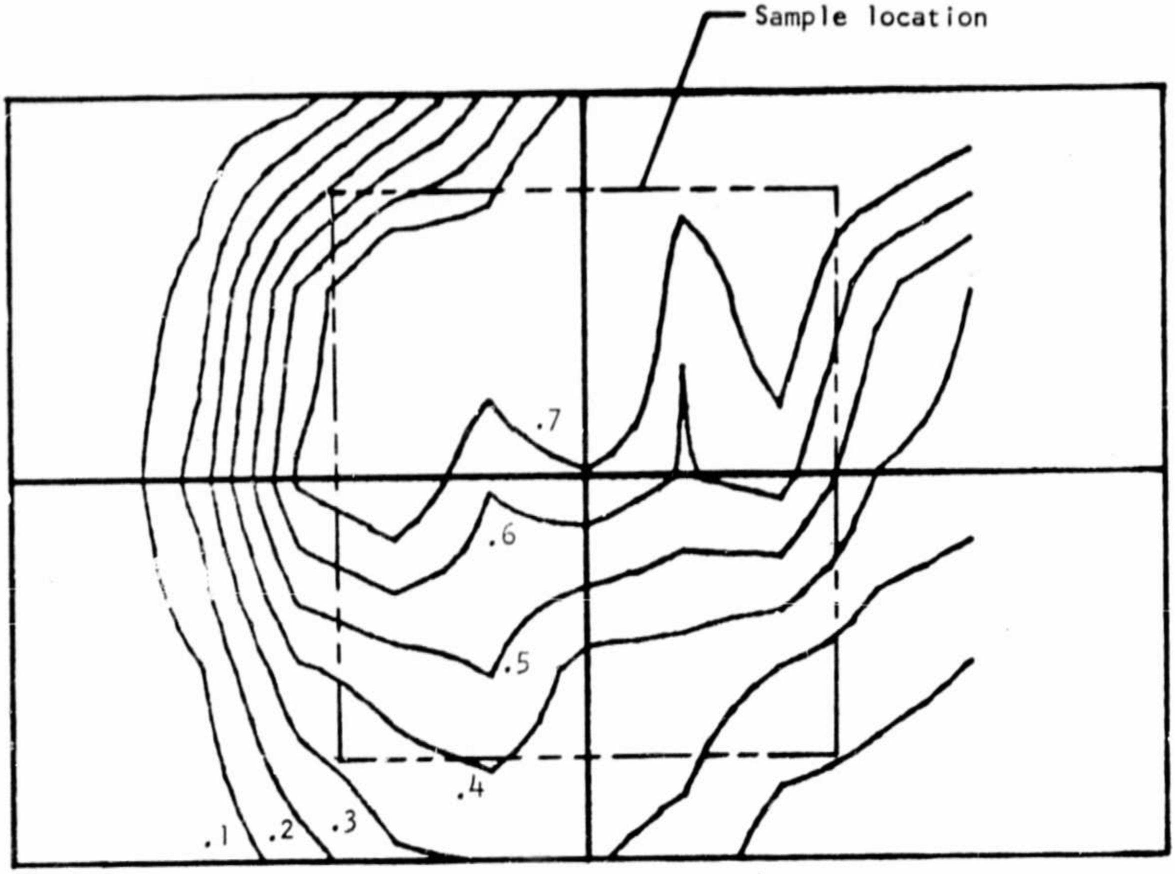


Figure 3. - Electron beam density contour, 5kV, 0.5nA/cm^2; data is in nA/cm^2.

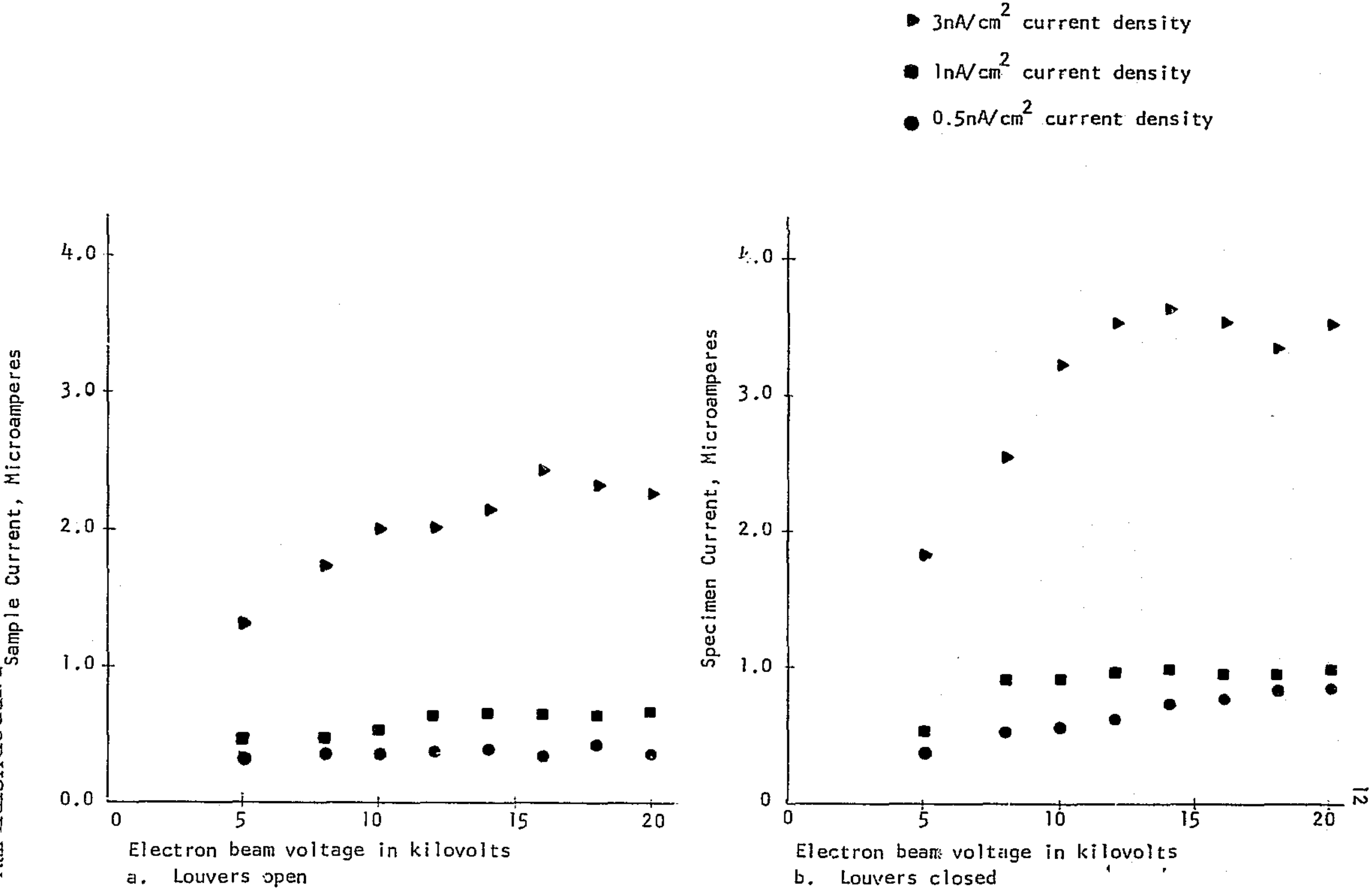


Figure A1. - Average specimen current as a function of beam voltage for the thermal louvers

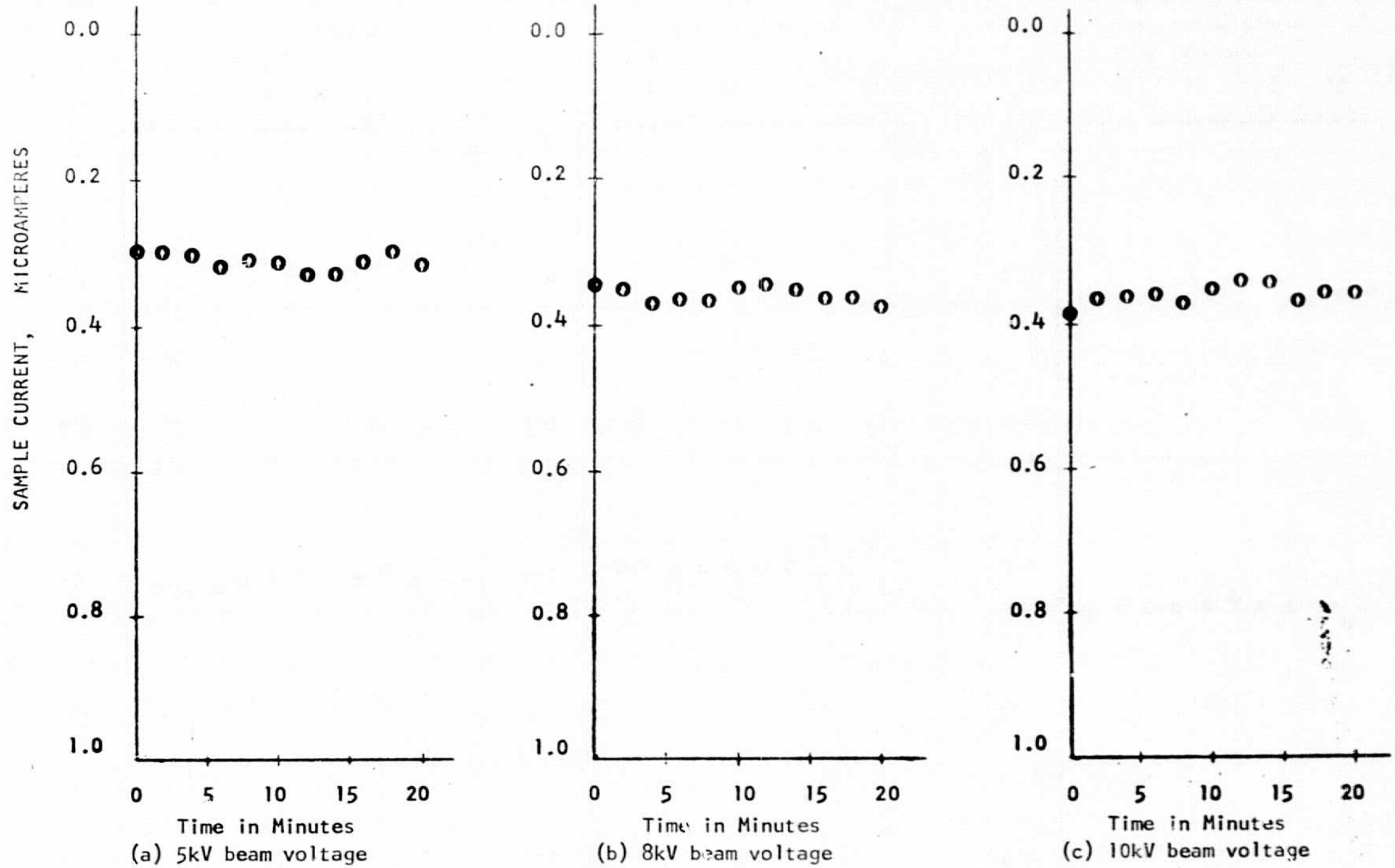


Figure A2. - Specimen current as a function of time for the thermal louvers in the open position with a 0.5nA/cm^2 current density

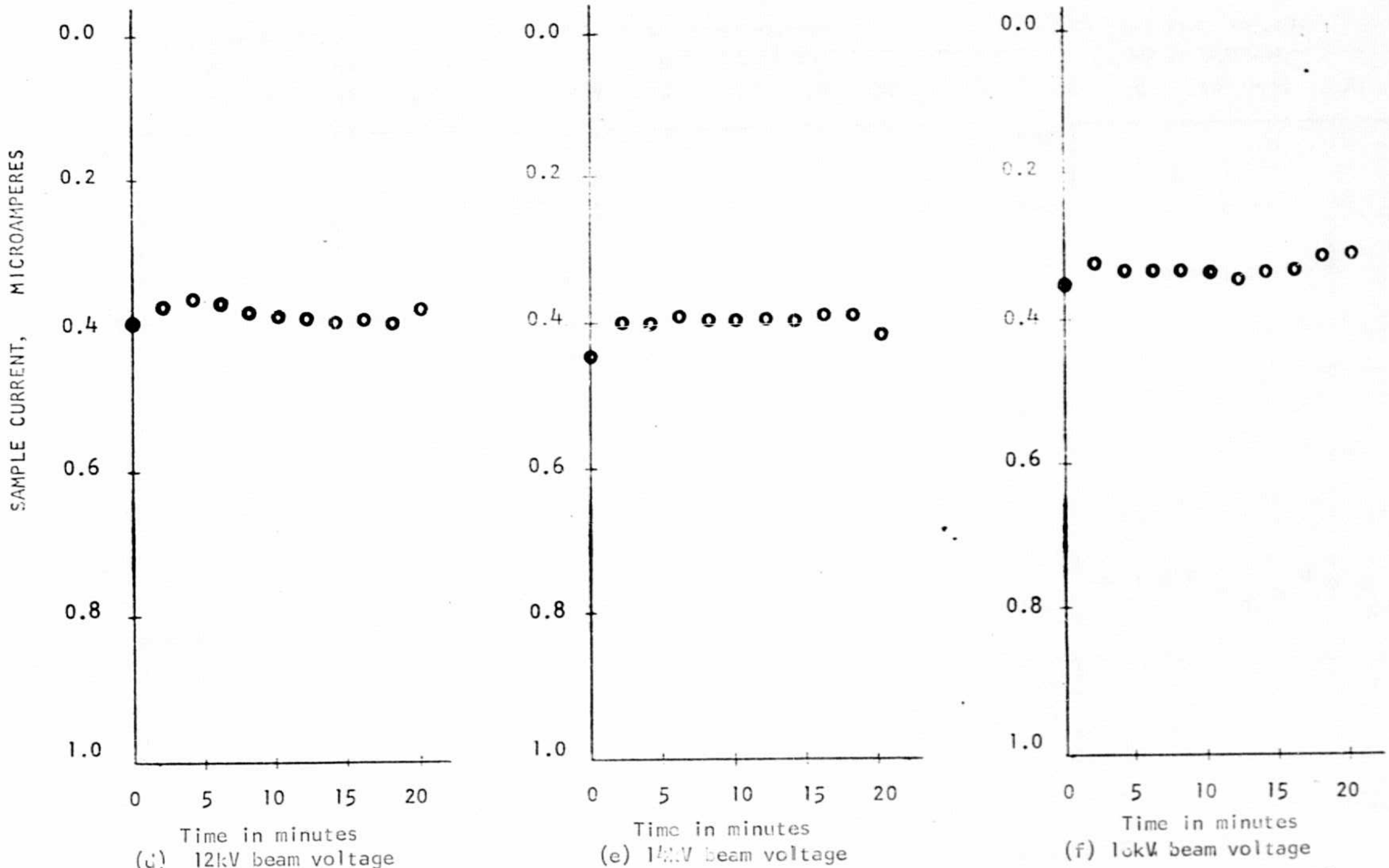
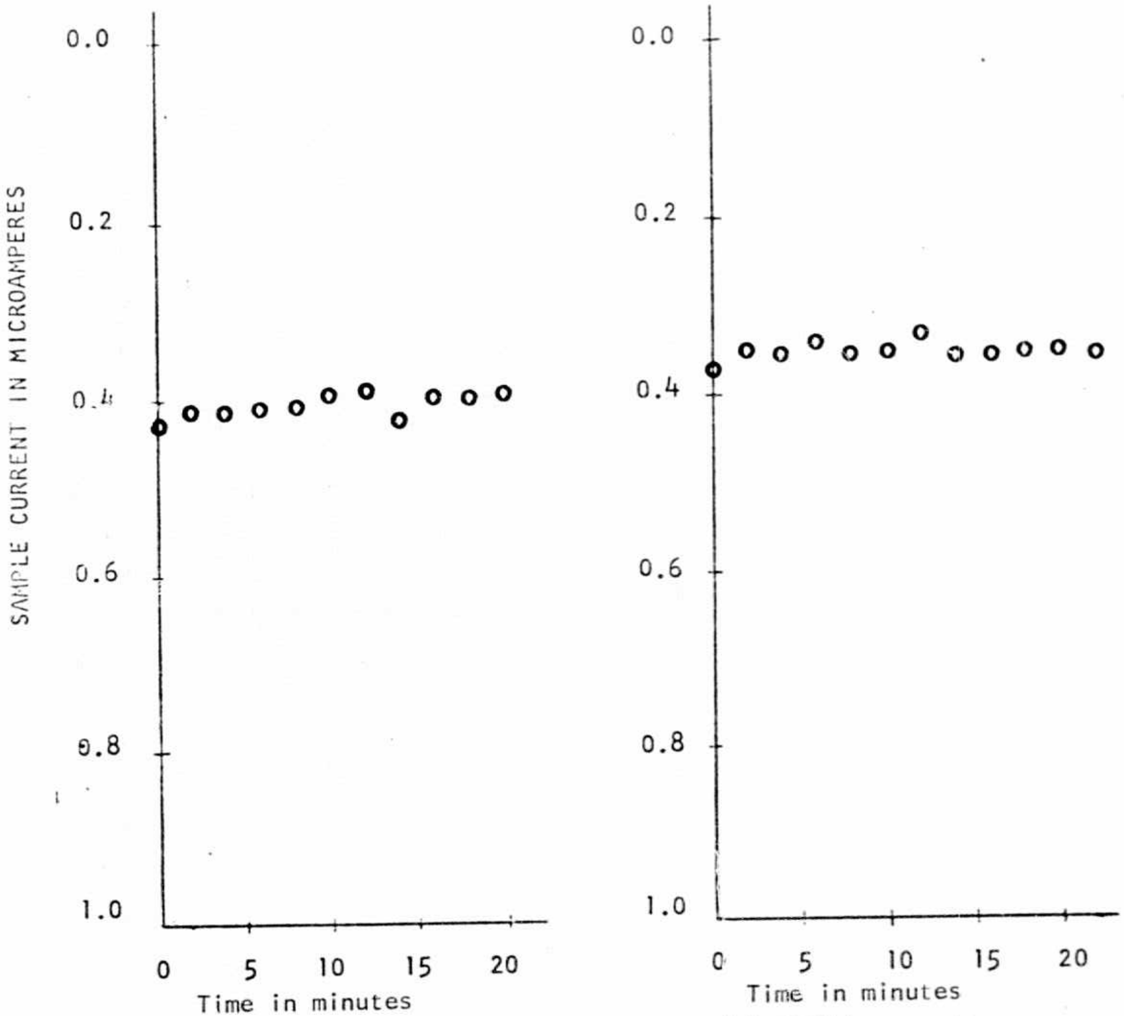


Figure A2. - Sample current as a function of time for the thermal louvers in the open position with a 0.5nA/cm^2 current density



(g) 18kV beam voltage

(h) 20kV beam voltage

Figure A2. - Specimen current as a function of time for the thermal louvers in the open position with a $0.5 nA/cm^2$ current density.

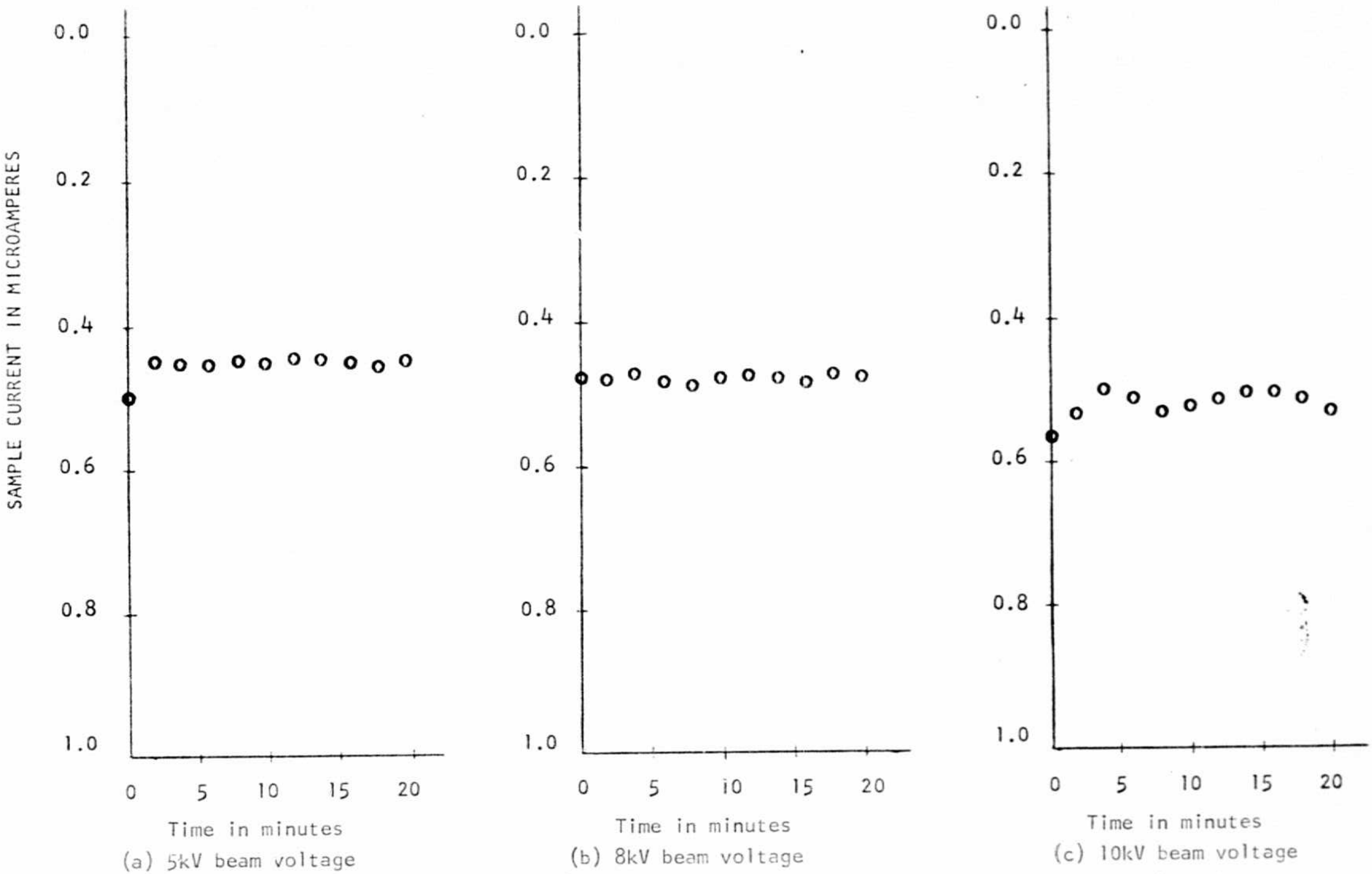


Figure A3. - Specimen current as a function of time for the thermal louvers in the open position with a 1nA/cm^2 beam density.

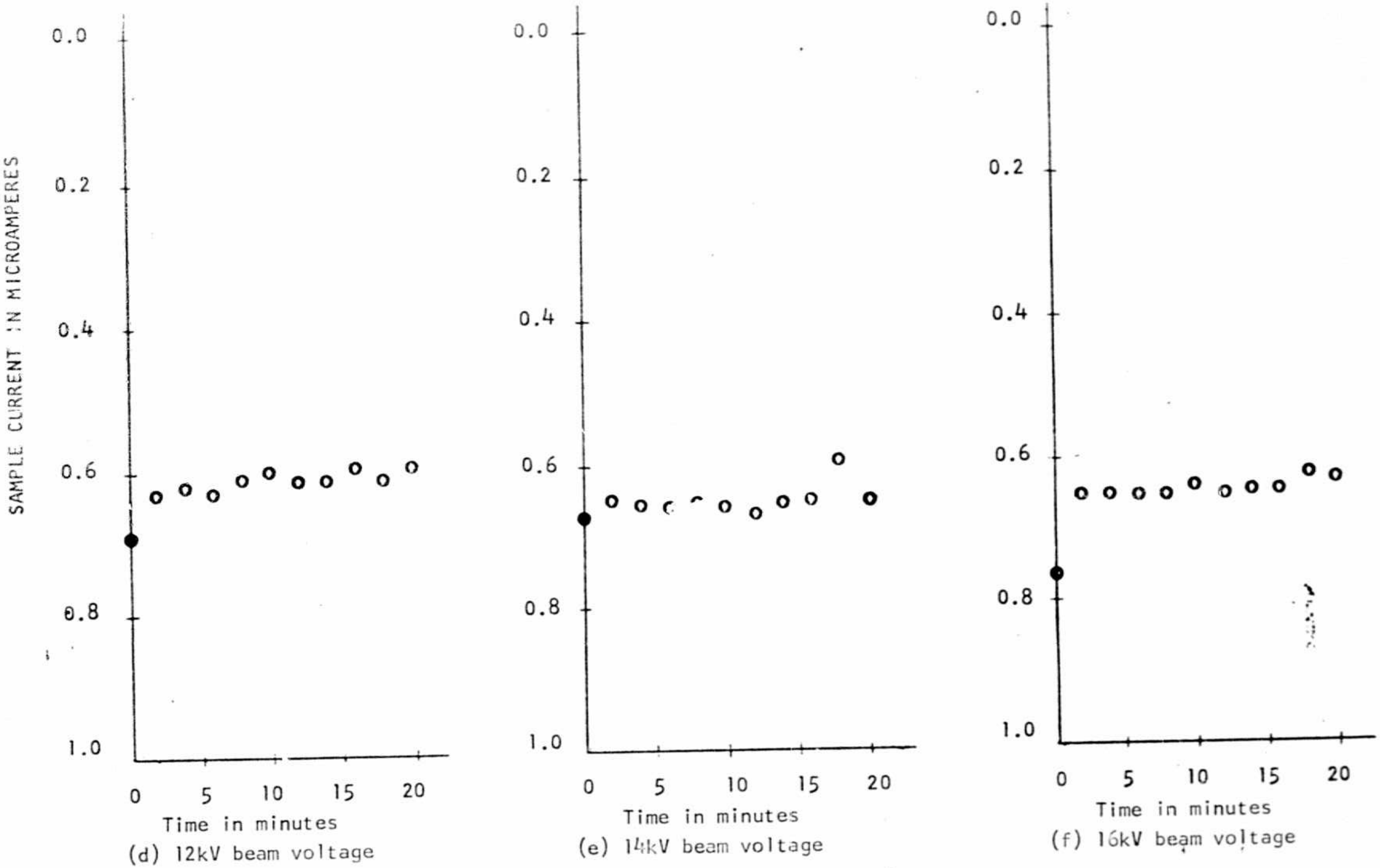


Figure A3.-Specimen current as a function of time for the thermal louvers in the open position with a 1nA/cm^2 current densi.v.

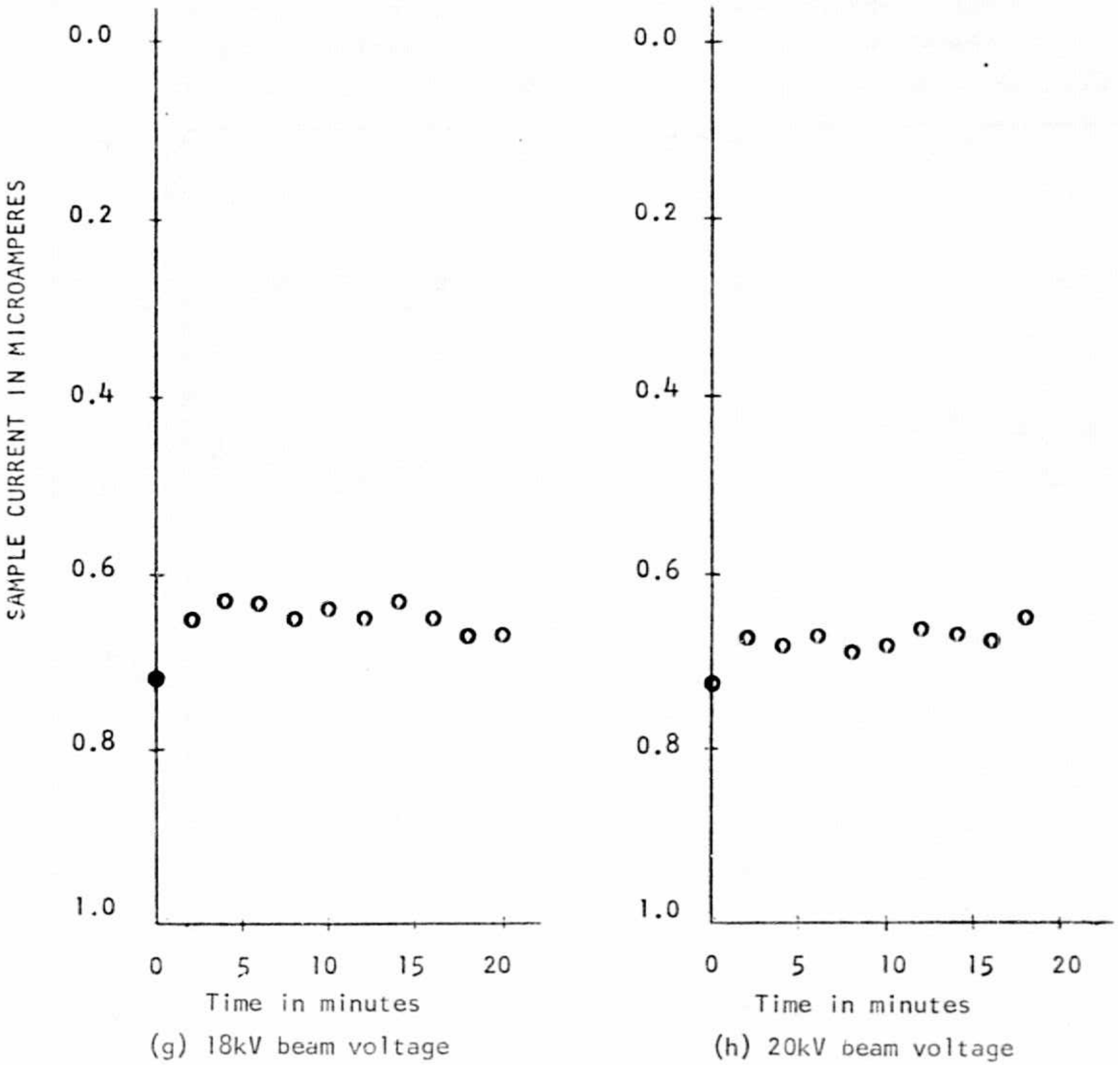
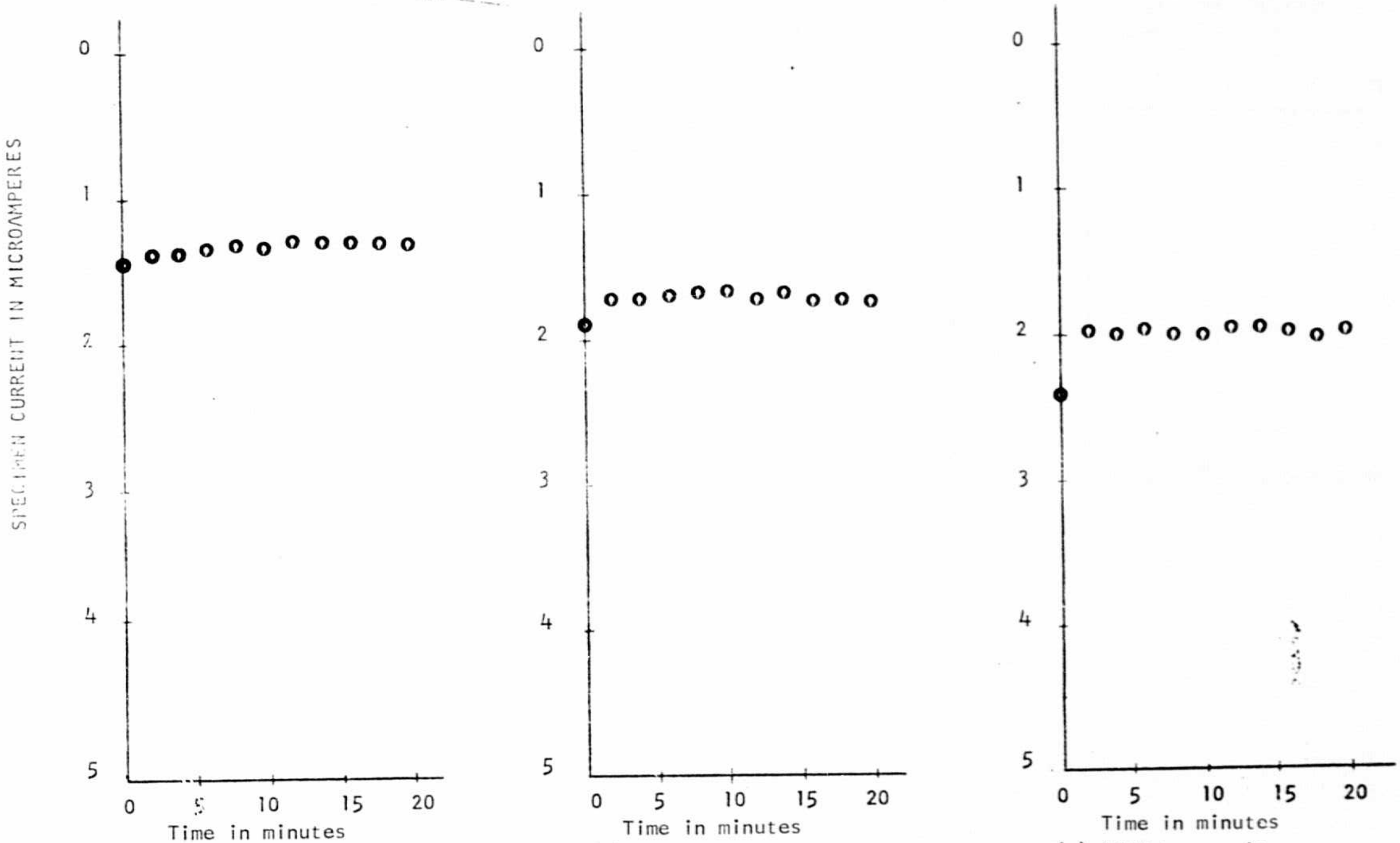
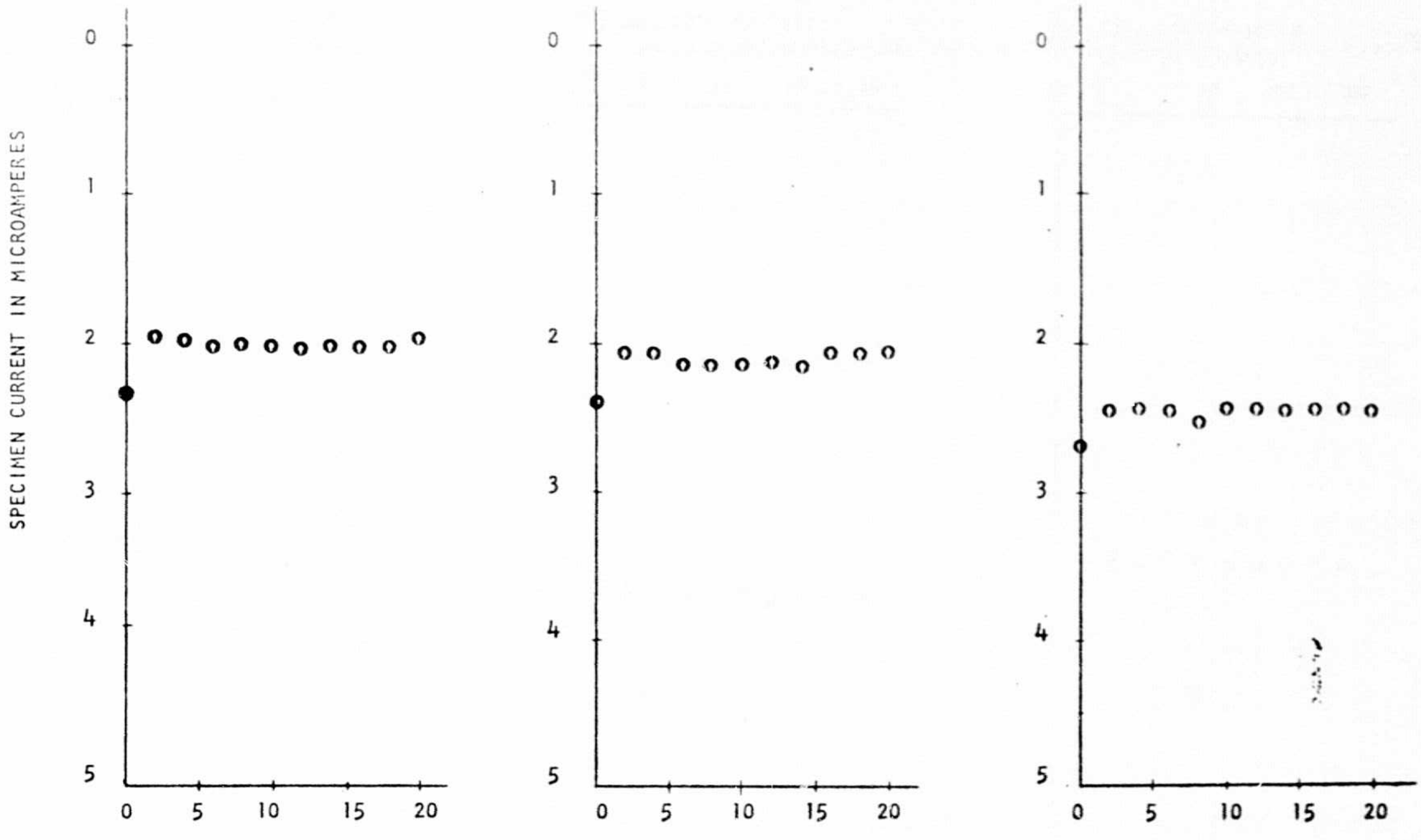


Figure A3. - Specimen current as a function of time for the thermal louvers in the open position with a $1.0 nA/cm^2$ current density



(a) 5kV beam voltage (b) 8kV beam voltage (c) 10kV beam voltage

Figure A4. - Specimen current as a function of time for the thermal louvers in the open position with a $3nA/cm^2$ current density.

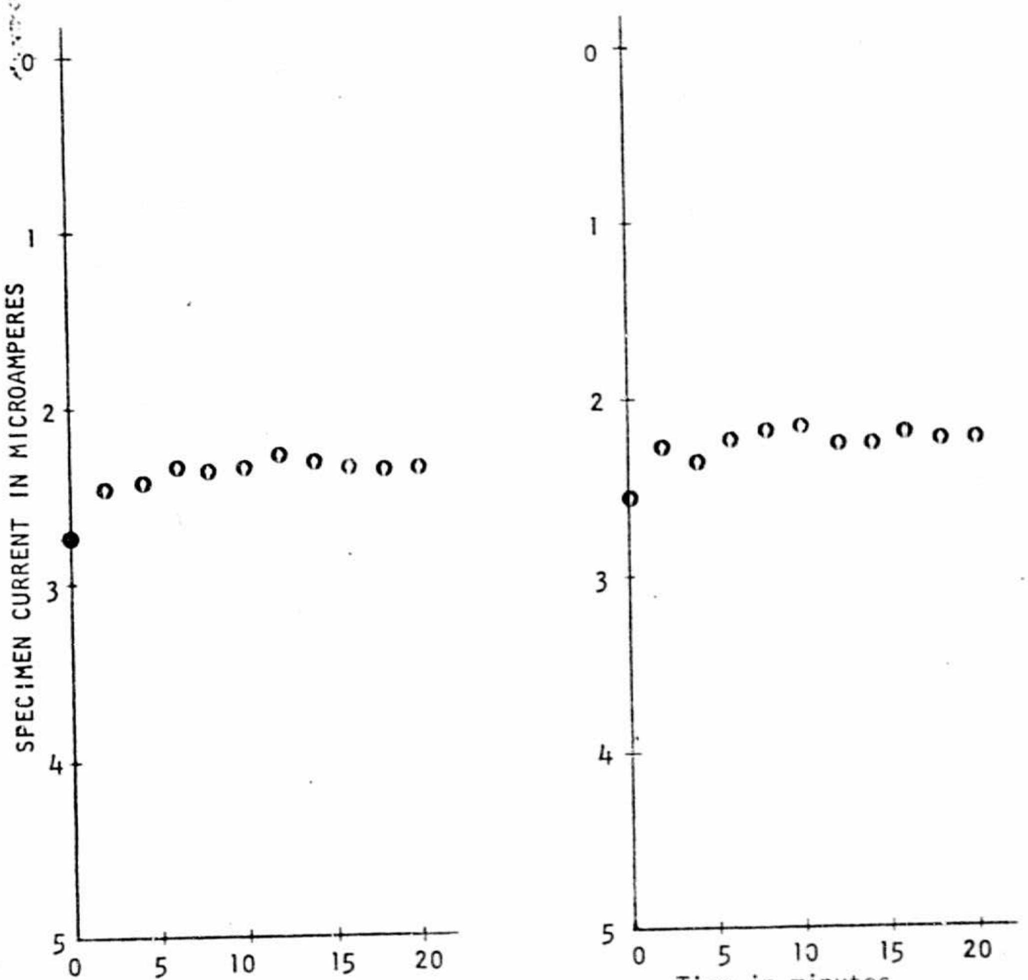


(d) 12kV beam voltage

Time in minutes
(e) 14kV beam voltage

Time in minutes
(f) 16kV beam voltage

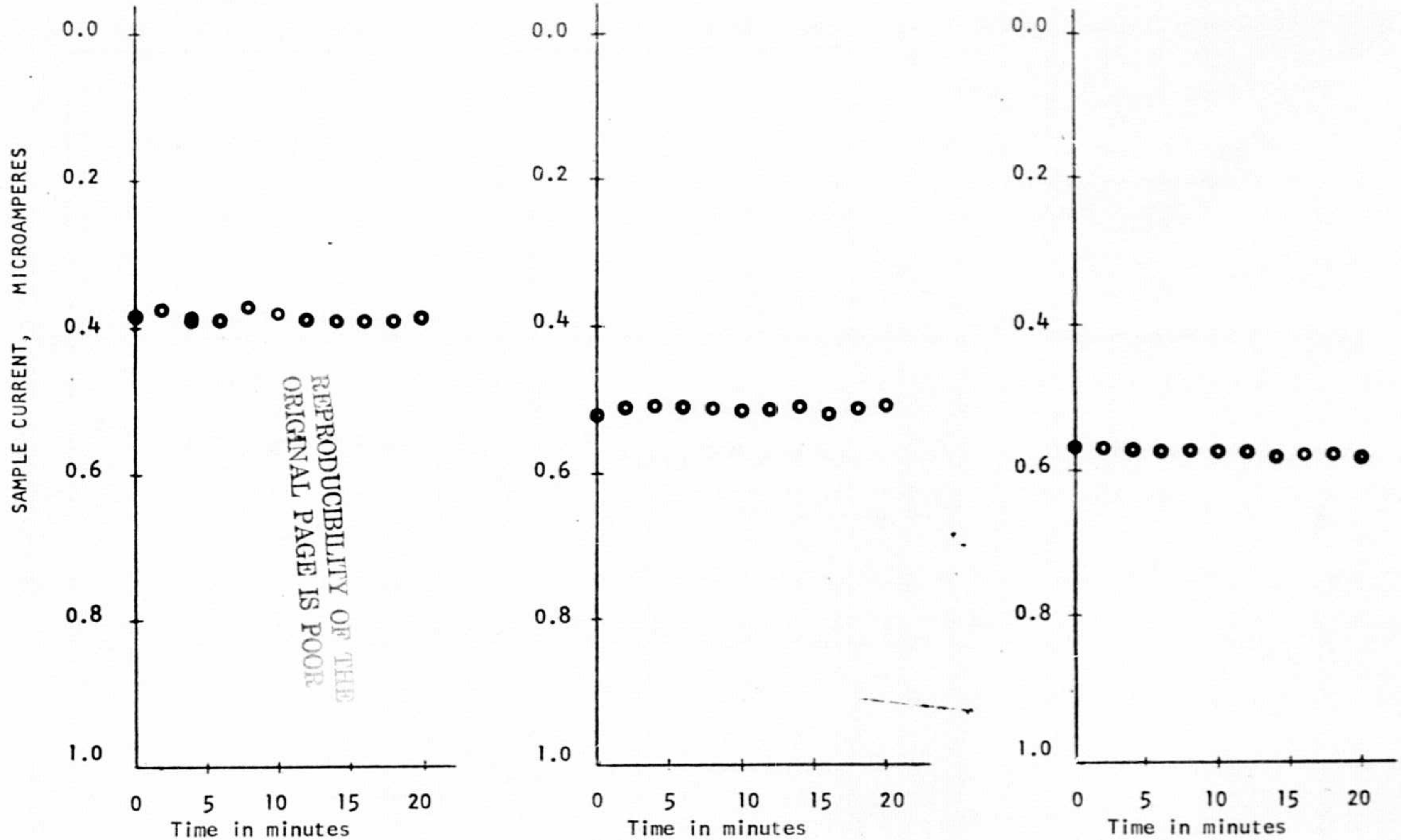
Figure A4. - Specimen current as a function of time for the thermal louvers in the open position with a $3nA/cm^2$ current density.



(g) 18kV beam voltage

(h) 20kV beam voltage

Figure A4. - Specimen current as a function of time for the thermal louvers in the open position with a $3nA/cm^2$ current density



(a) 5kV beam voltage

(b) 8kV beam voltage

(c) 10kV beam voltage

Figure A5. - Specimen current as a function of time for the thermal louvers in the closed position with a $0.5 nA/cm^2$ current density

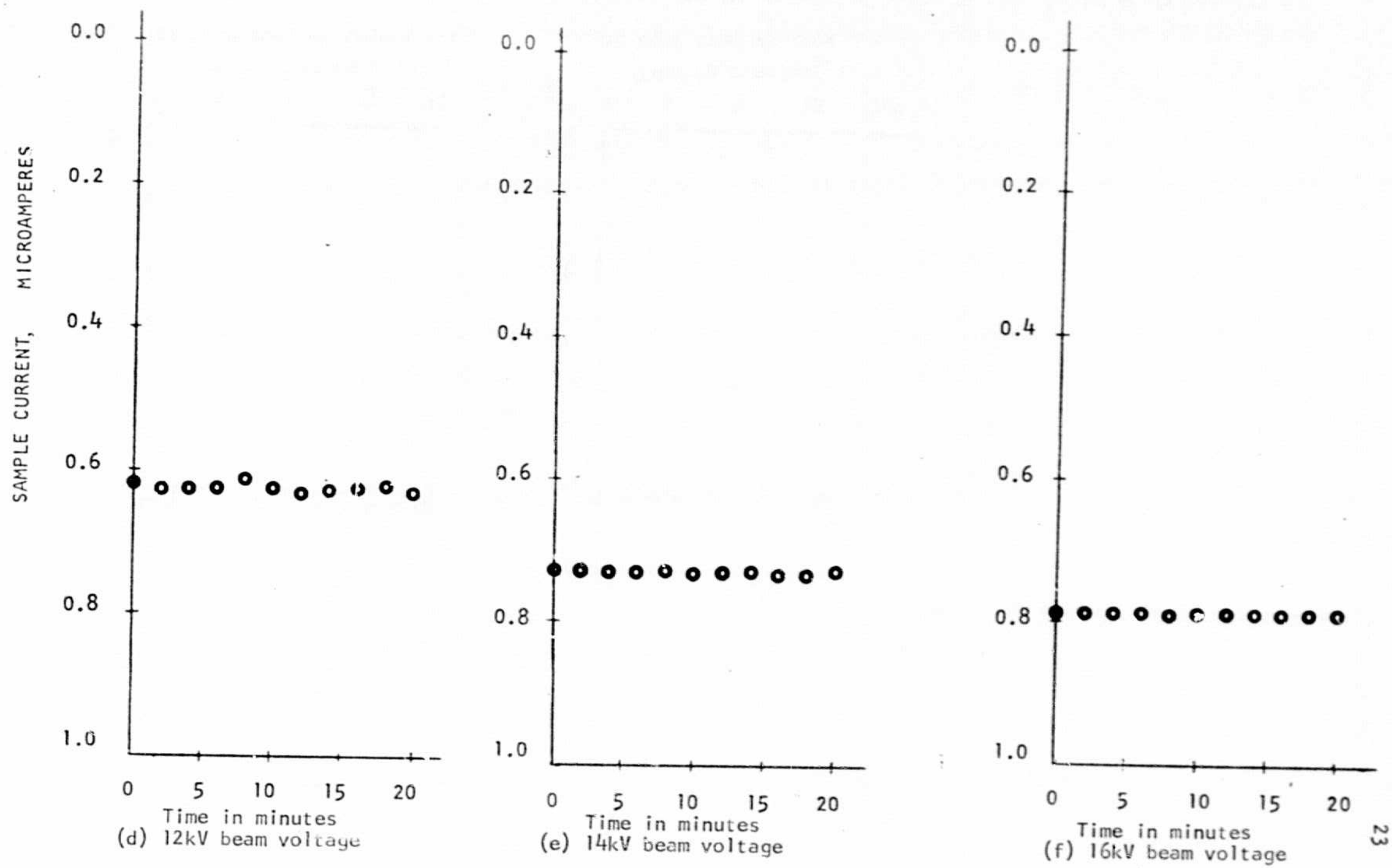


Figure A5. - Specimen current as a function of time for the thermal louvers in the closed position with a 0.5 nA/cm^2 current density

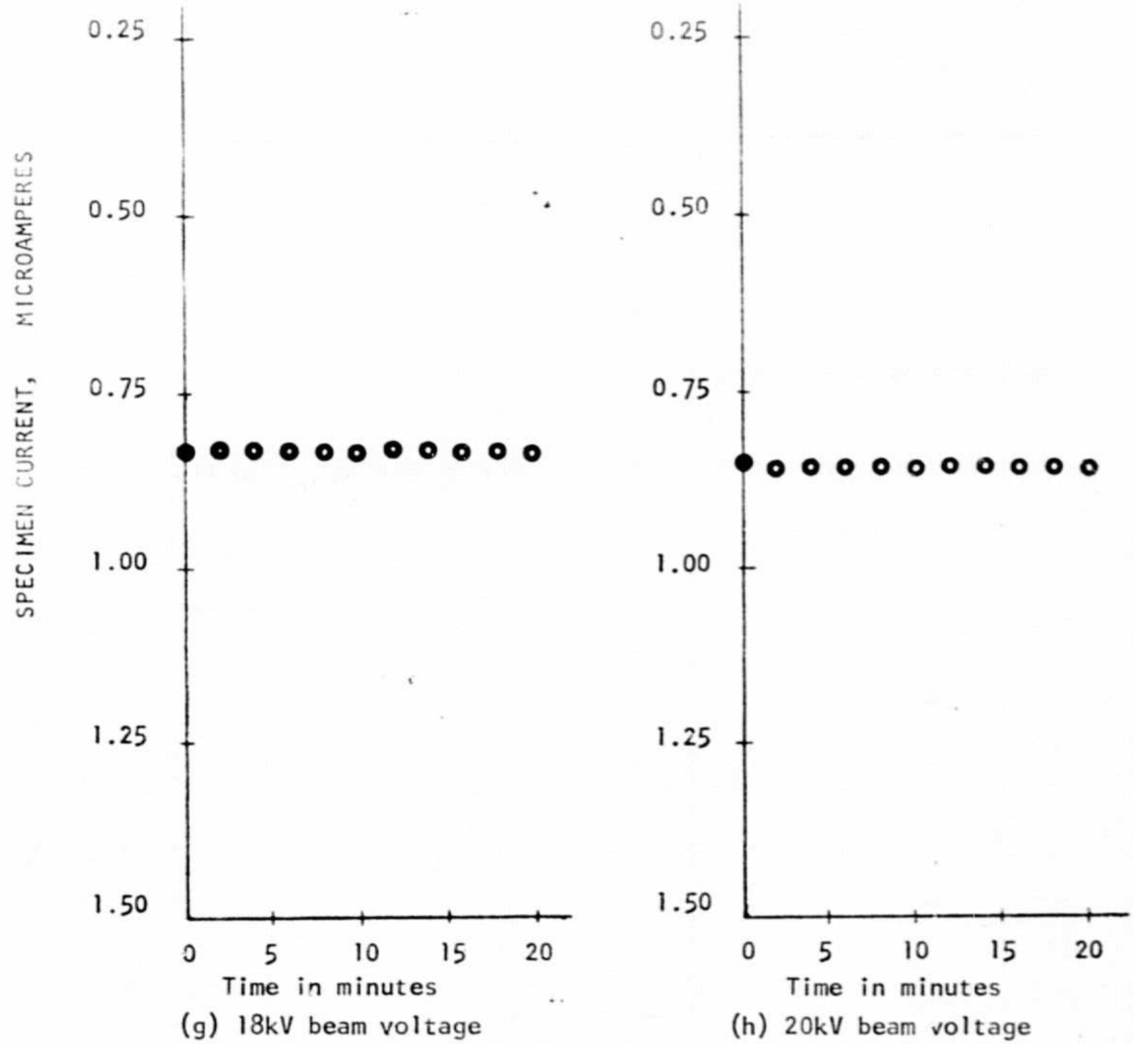


Figure A5. - Specimen current as a function of time for the thermal louvers in the closed position with a $0.5 nA/cm^2$ current density

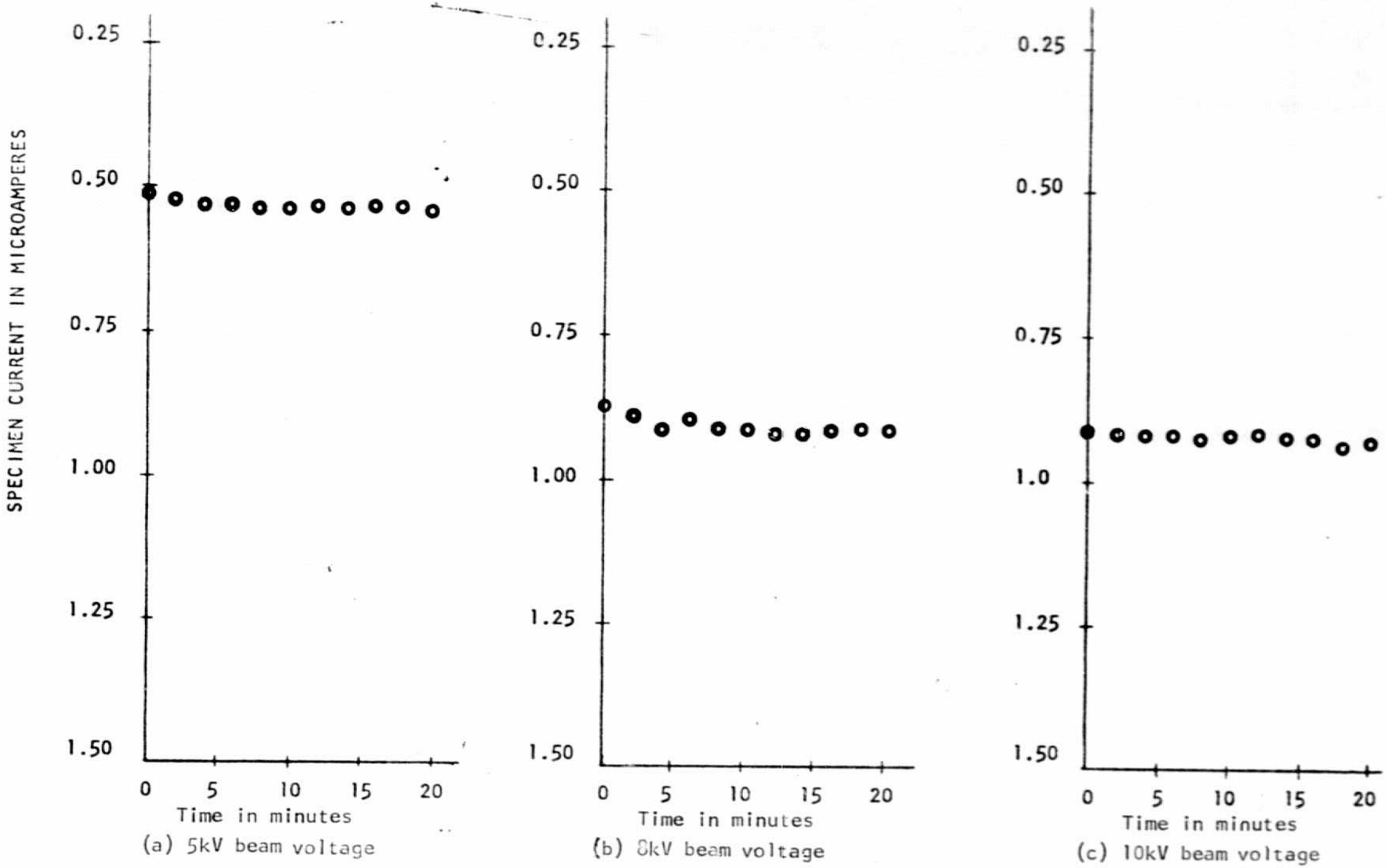
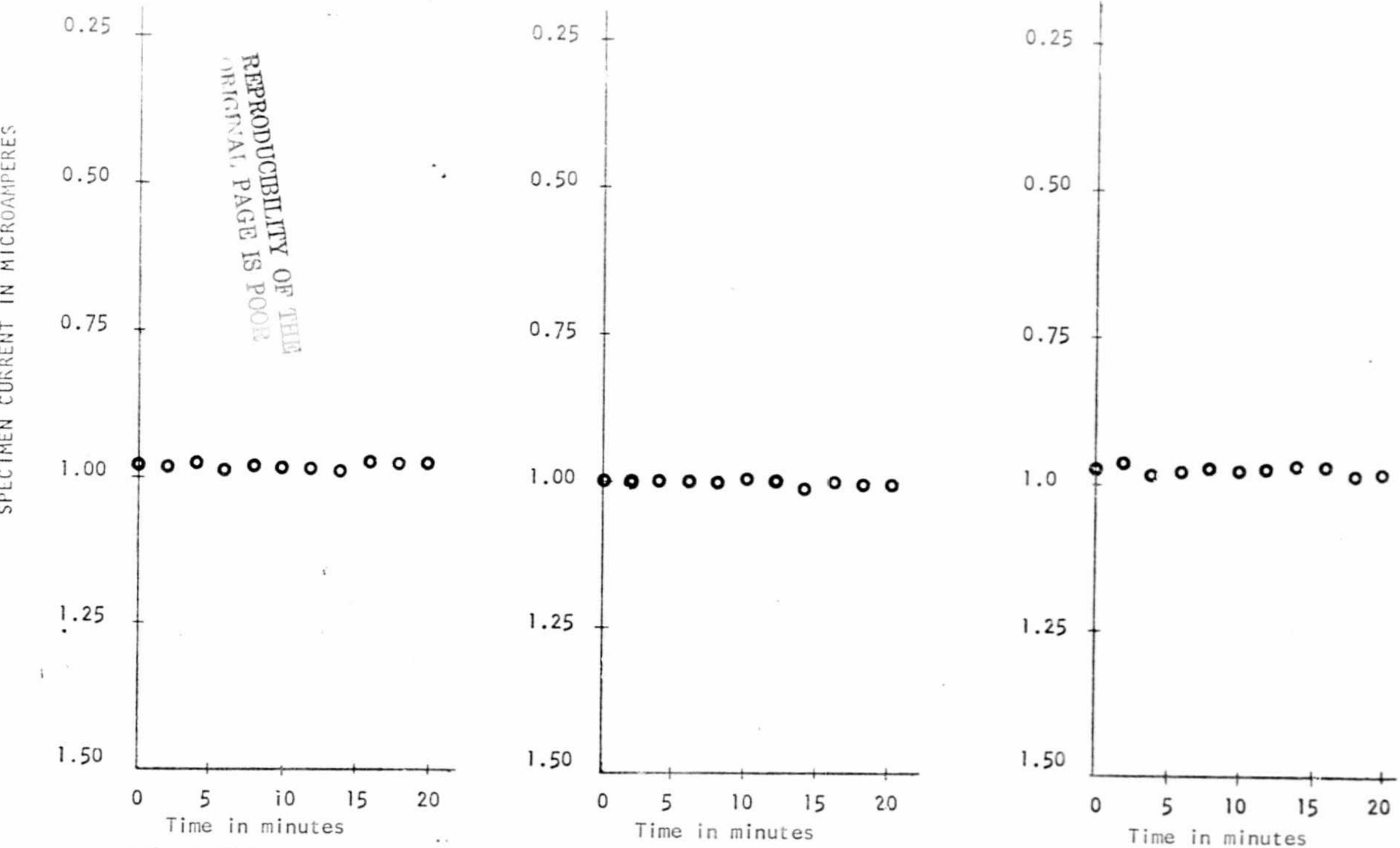


Figure A6. - Specimen current as a function of time for the thermal louvers in the closed position with a $1 nA/cm^2$ current density.



(d) 12kV beam voltage

(e) 14kV beam voltage

(f) 16kV beam voltage

Figure A6. - Specimen current as a function of time for the thermal louvers in the closed position with a $1 nA/cm^2$ current density

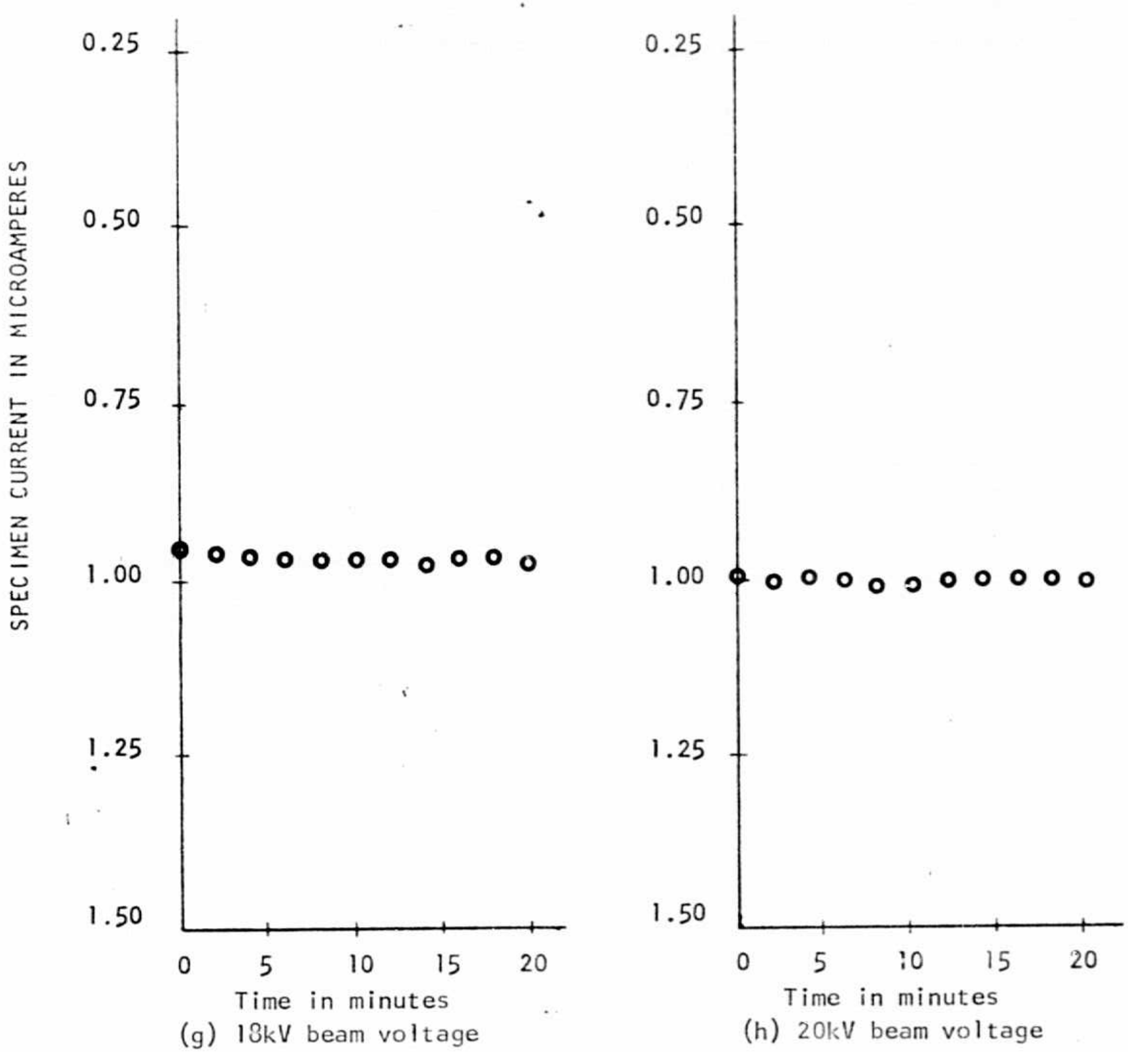
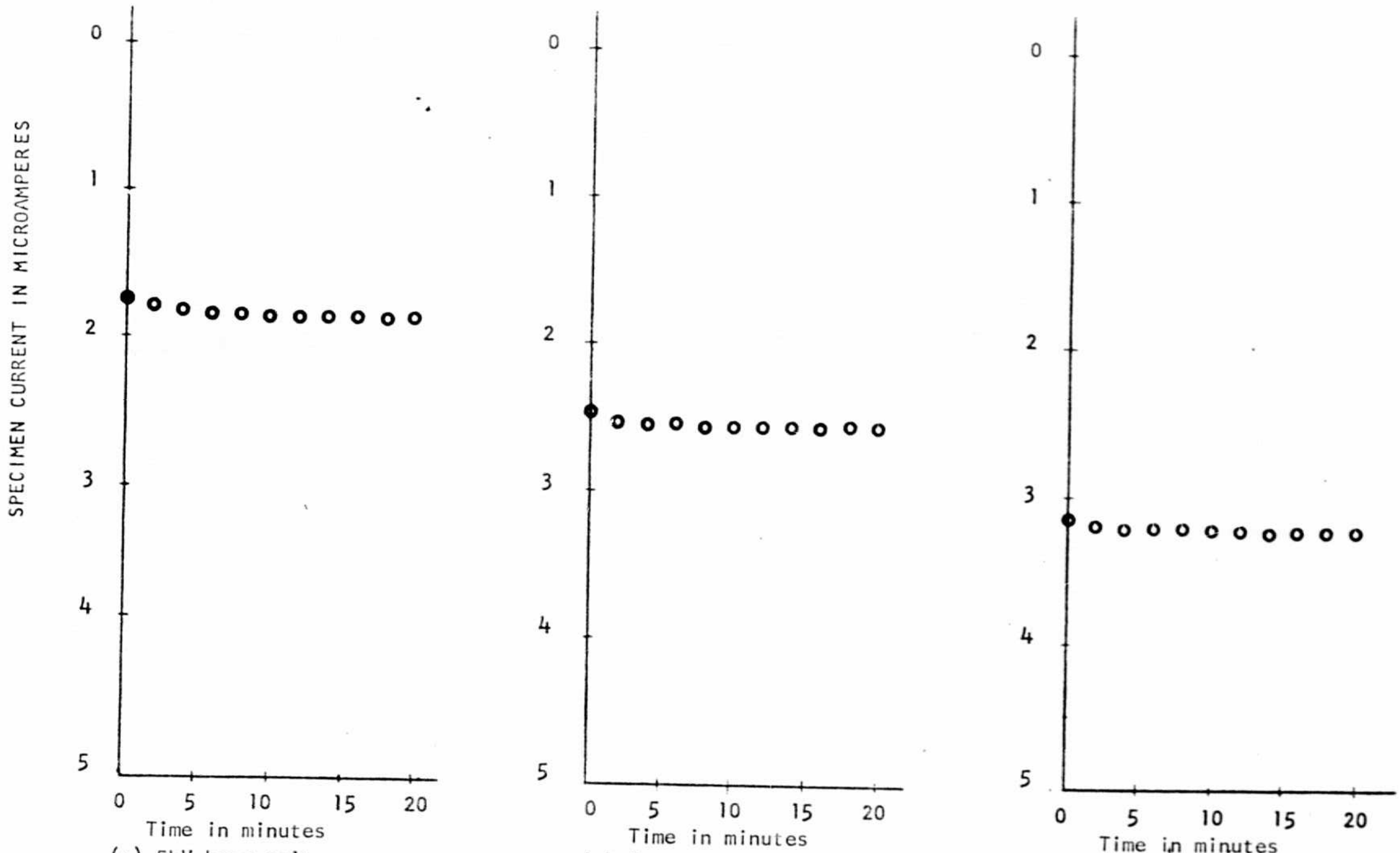


Figure A6. - Specimen current as a function of time for the thermal louvers in the closed position with a $1 nA/cm^2$ current density.

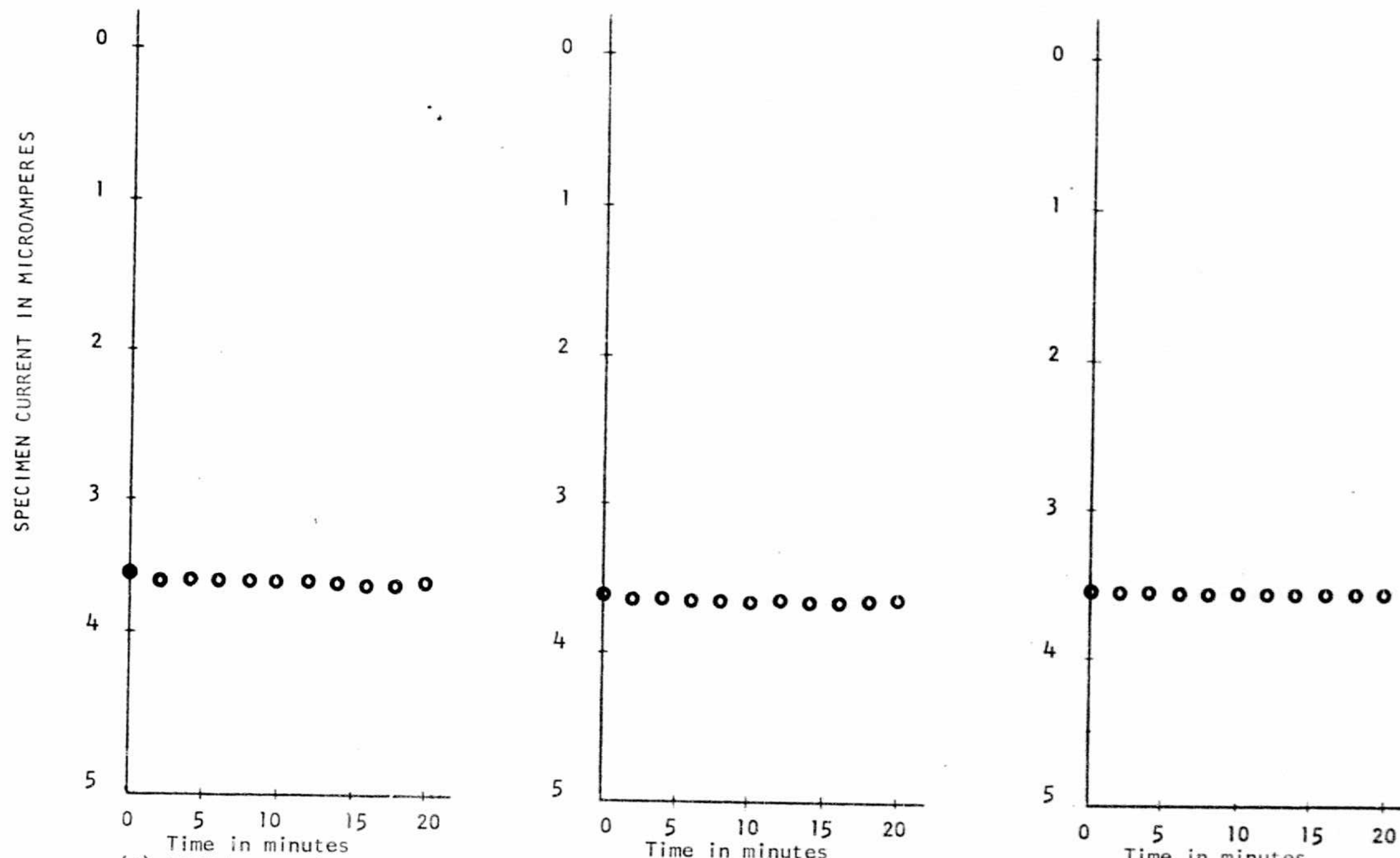


(a) 5kV beam voltage

(b) 8kV beam voltage

(c) 10kV beam voltage

Figure A7. - Specimen current as a function of time for the thermal louvers in the closed position with a $3nA/cm^2$ current density.

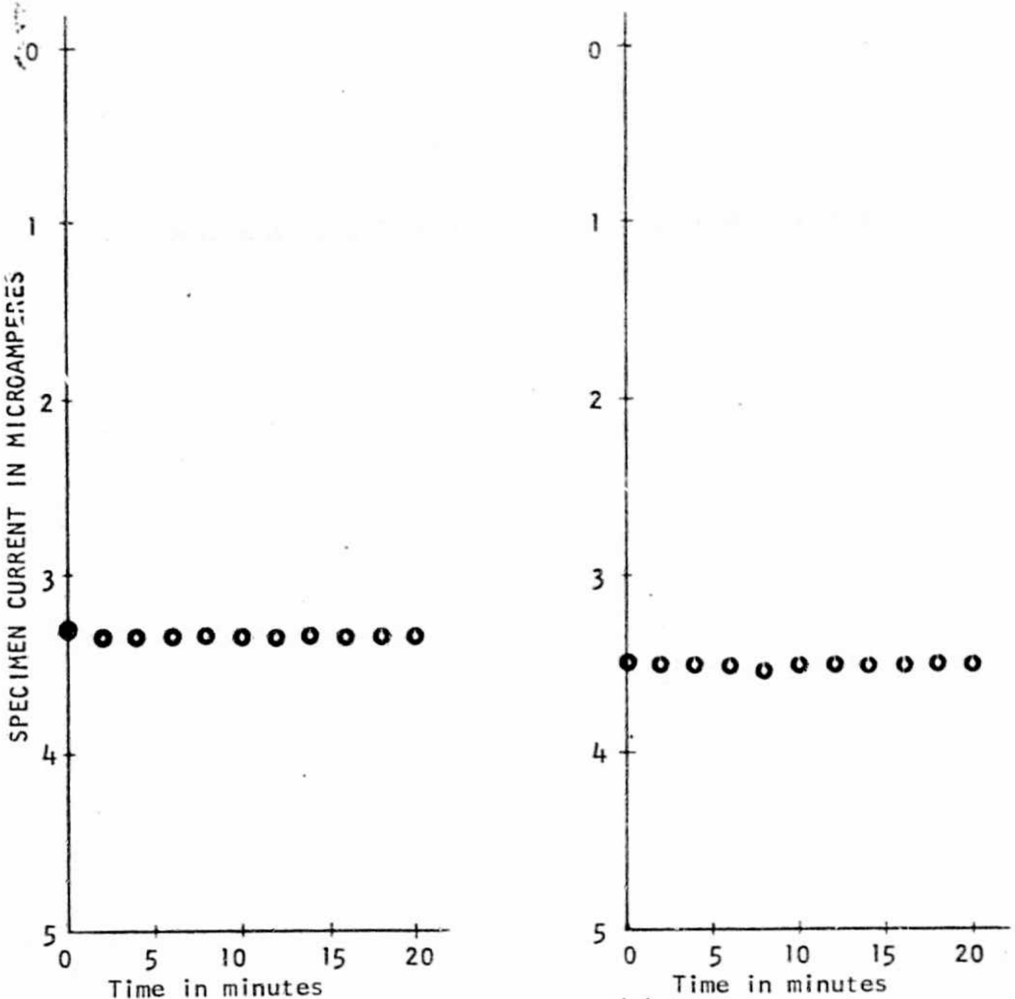


(d) 12kV beam voltage

(e) 14kV beam voltage

(f) 16kV beam voltage

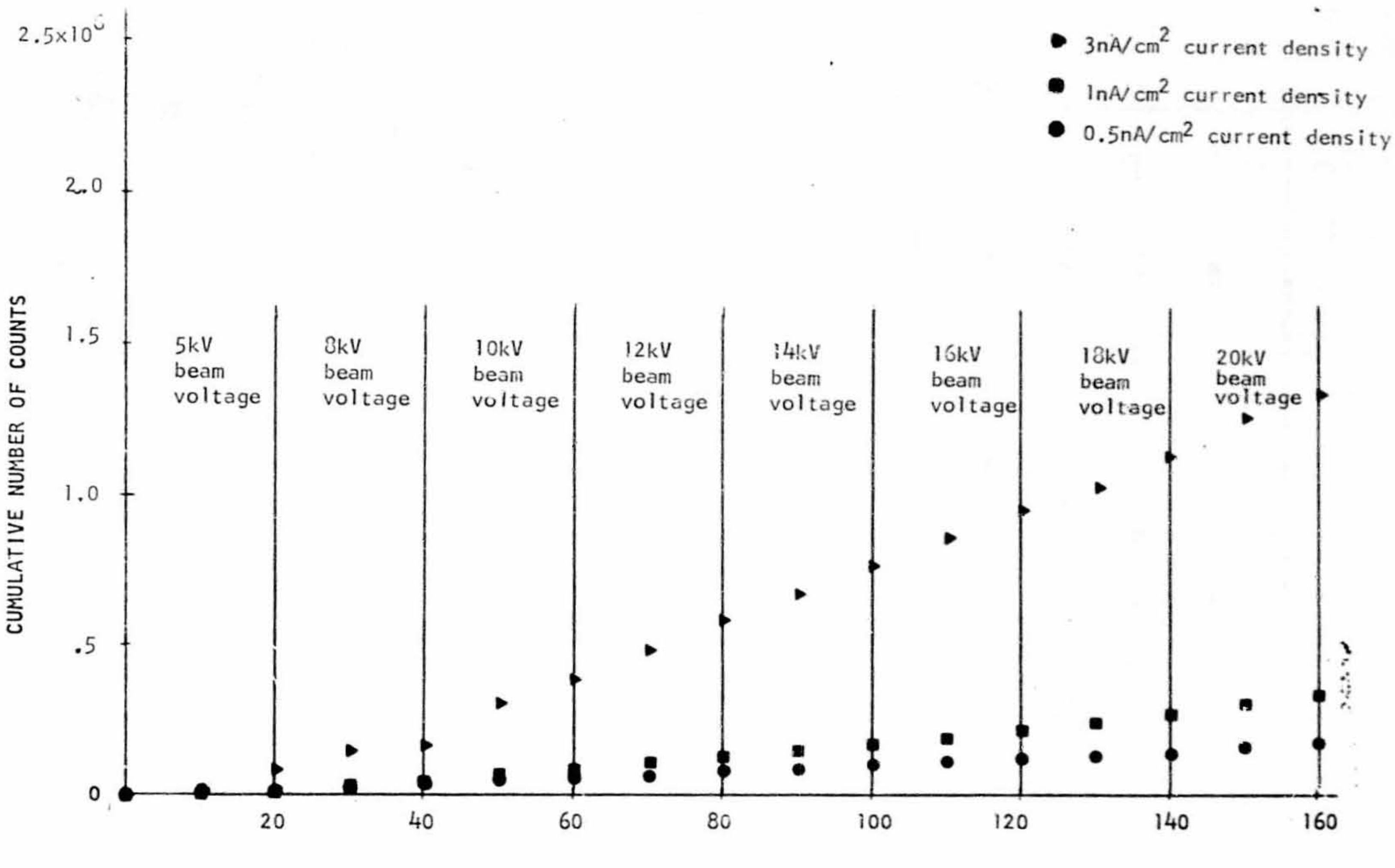
Figure A7. - Specimen current as a function of time for the thermal louvers in the closed position with a $3nA/cm^2$ current density.



(g) 18kV beam voltage

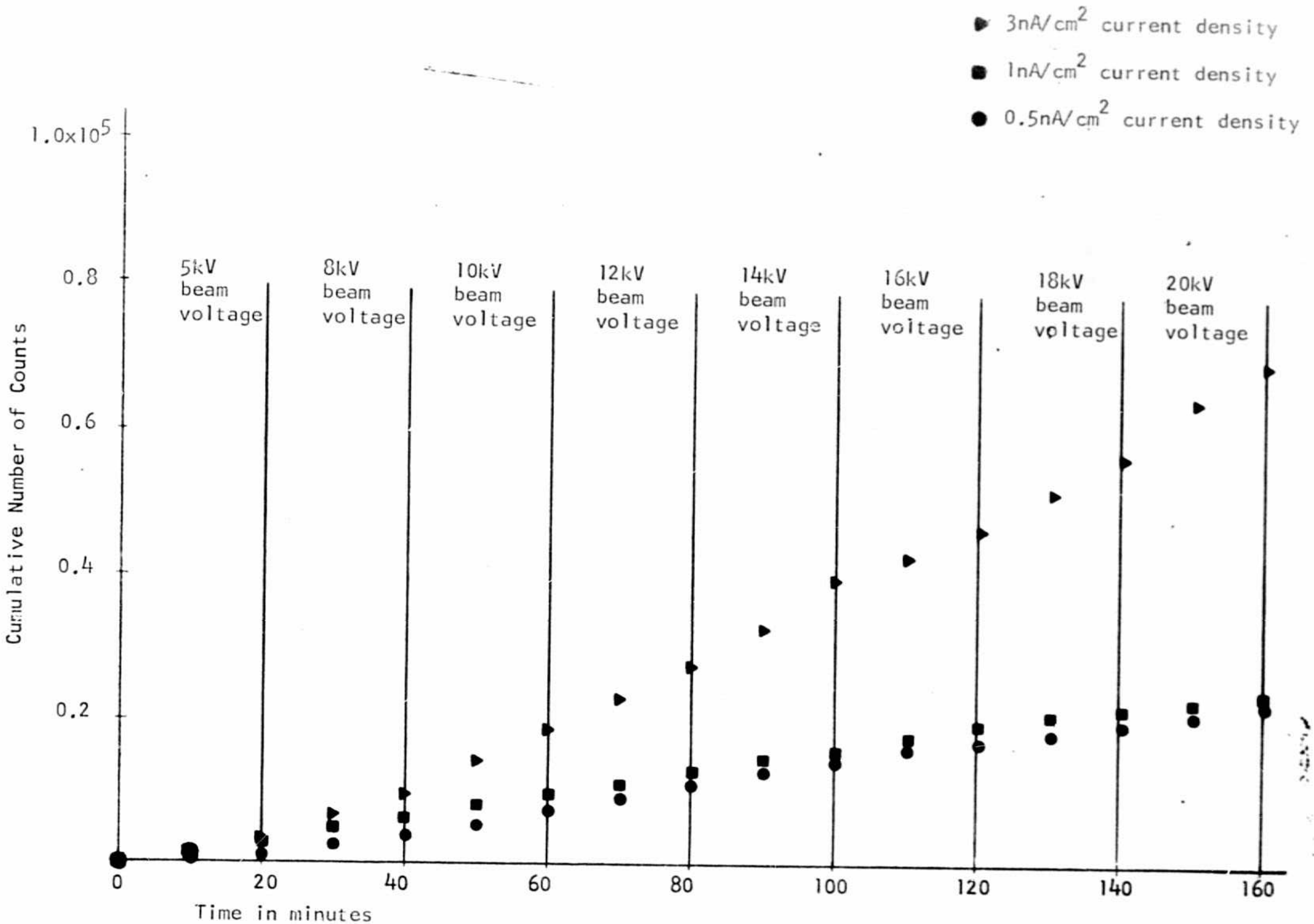
(h) 20kV beam voltage

Figure A7. - Specimen current as a function of time for the thermal louvers in the closed position with a $3nA/cm^2$ current density



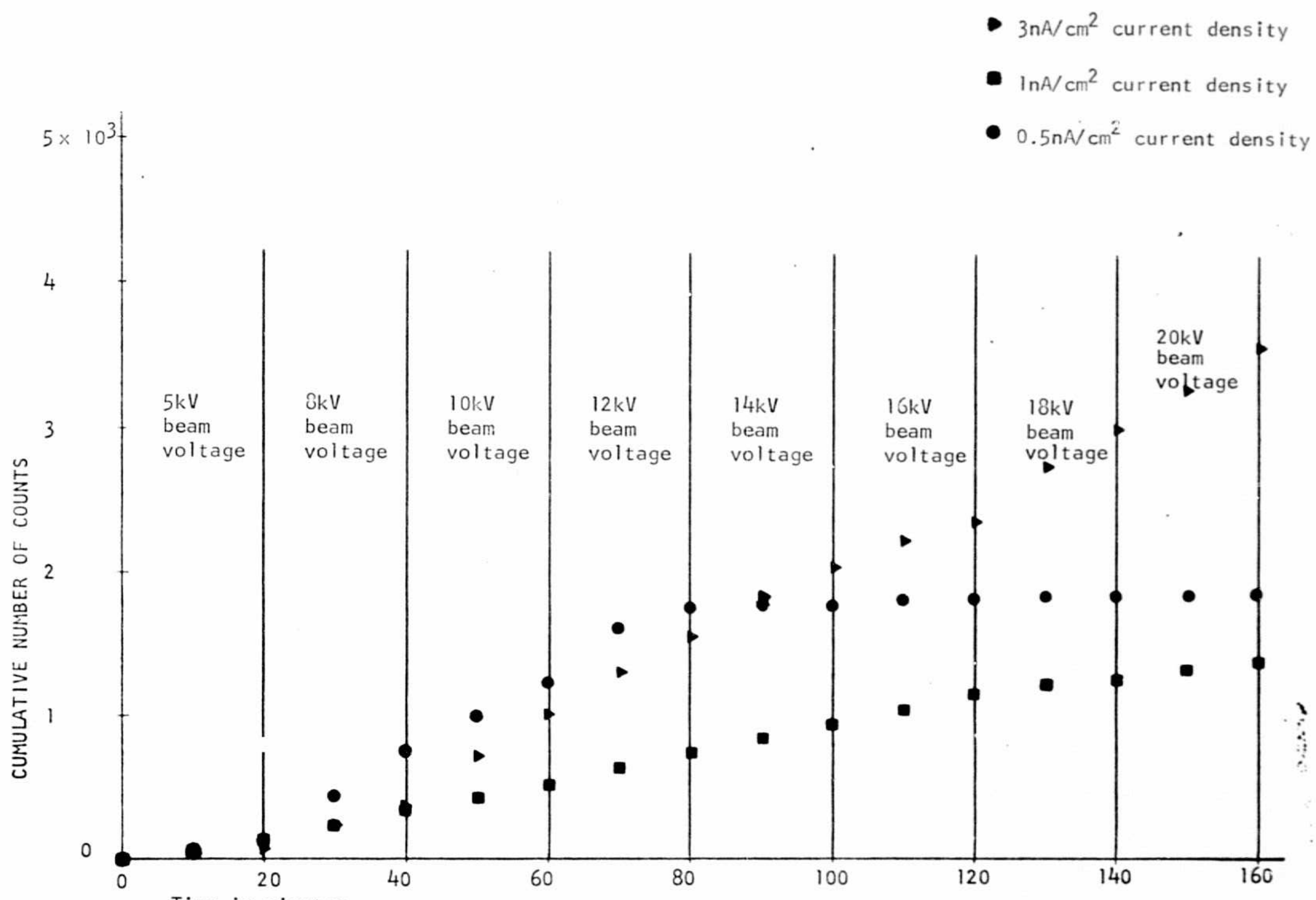
(a) Discharges of 0.5v or greater

re A8. - Cumulative number of discharges for the thermal louvers in the closed position



(·) Discharges of 2.0V or greater

. - Cumulative number of discharges for thermal louvers in the closed position.



(c) discharges greater than 5v

Figure A8. - Cumulative number of discharges for thermal louvers in the closed position.

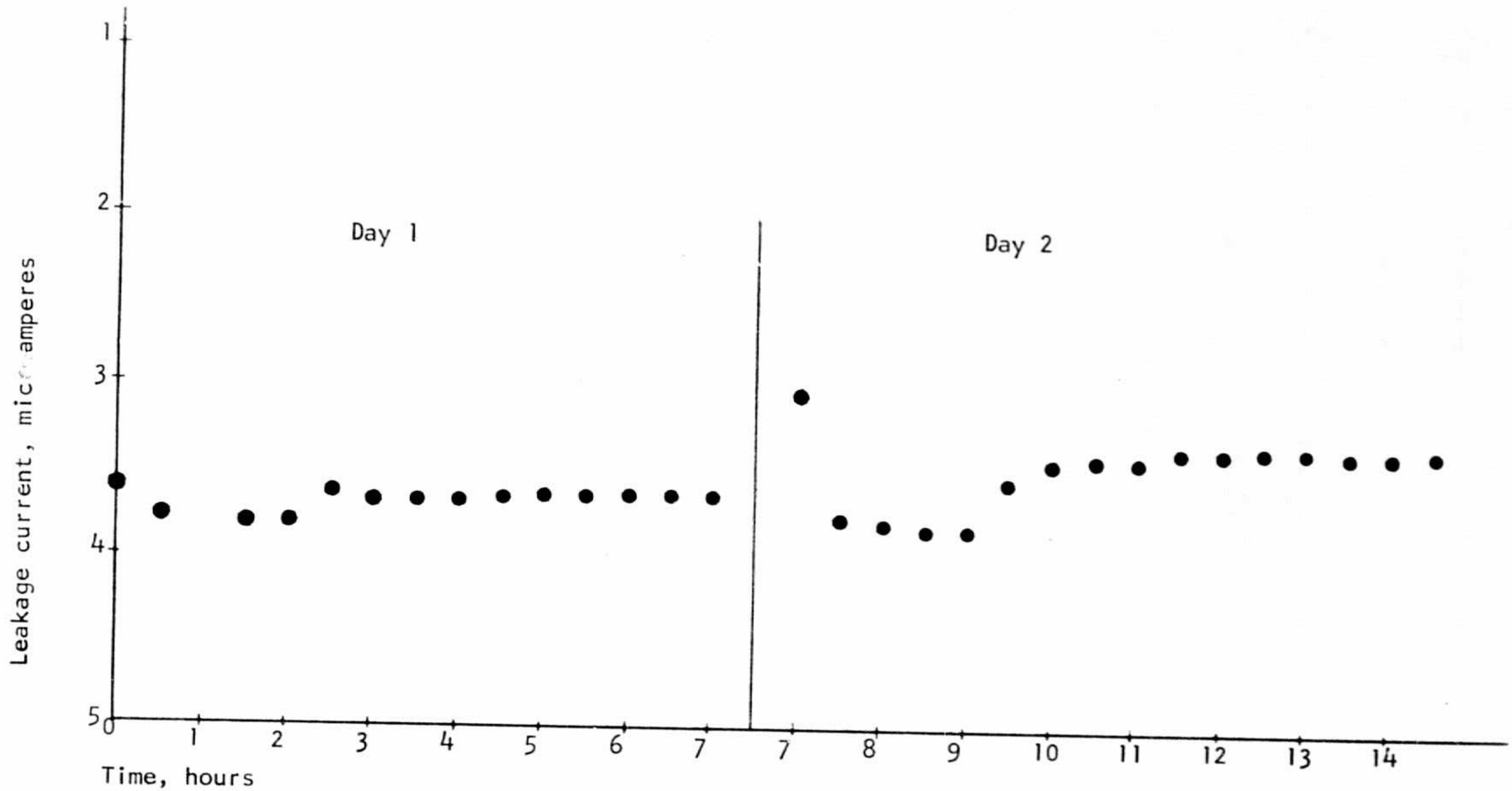
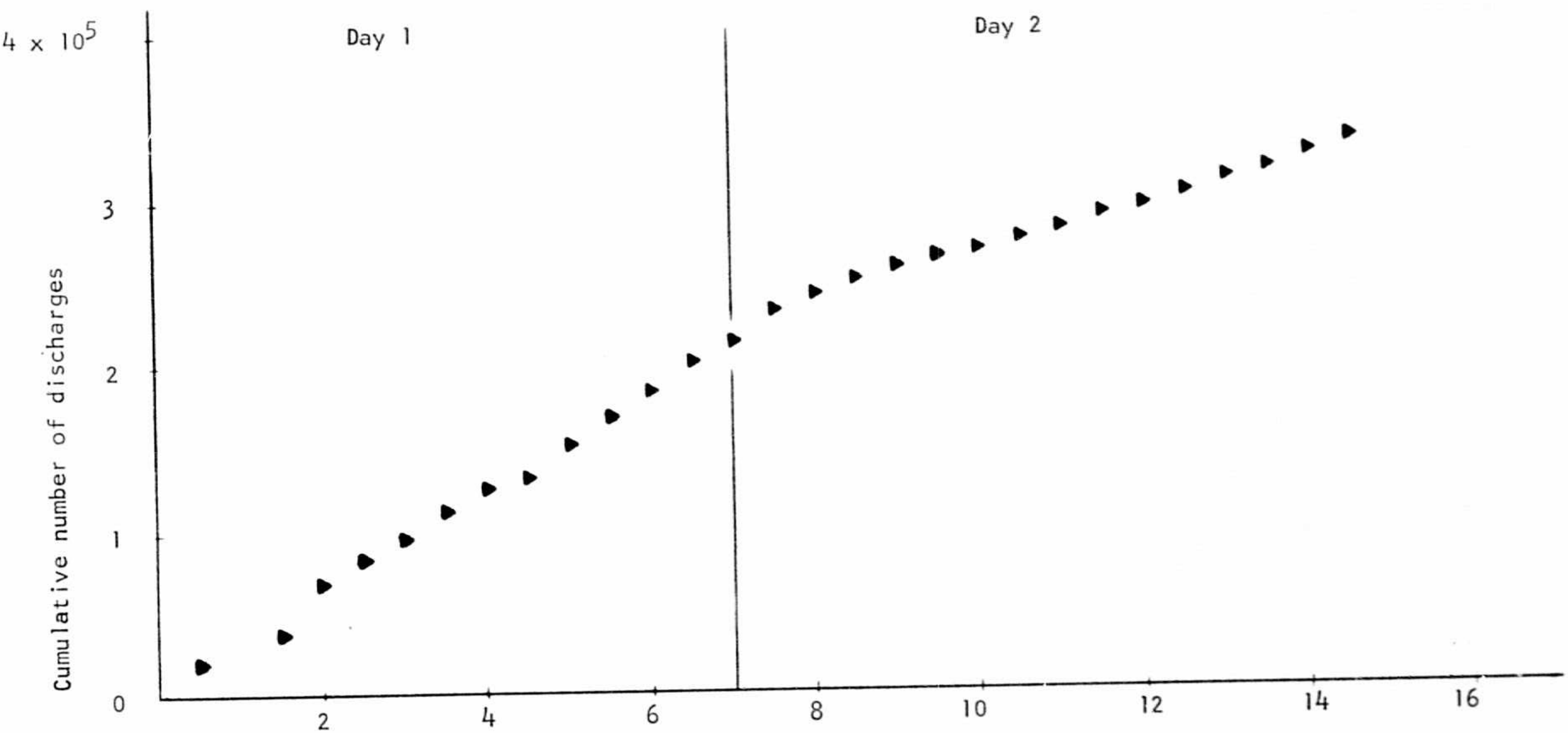
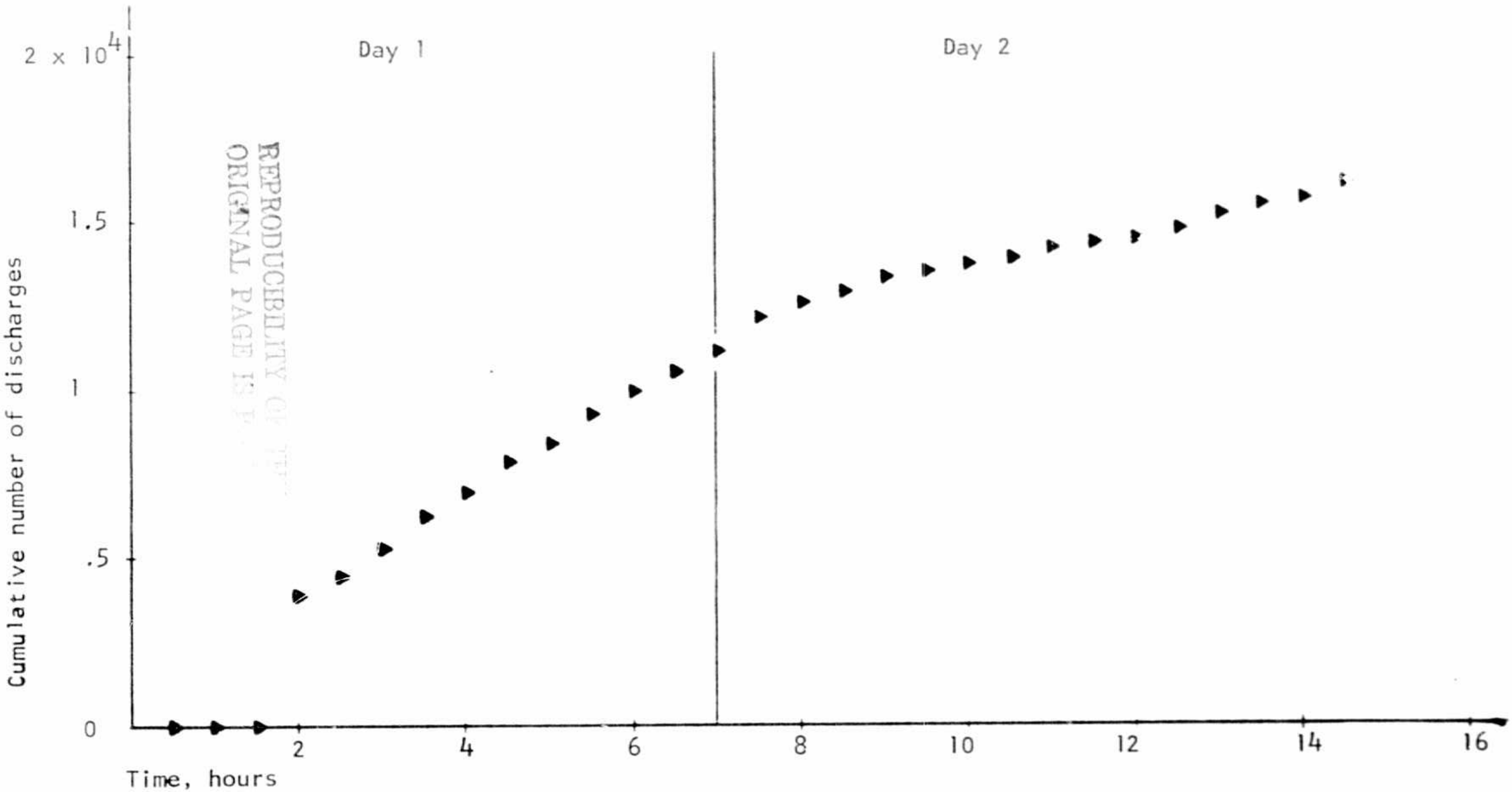


Figure A9. - Test item leakage current as a function of time for the louvers in the closed position with a $3nA/cm^2$ current density and 20kV beam voltage.



Time, hours
(a) Discharges greater than 2 volts.

Figure A10. - Cumulative number of discharges for the louvers in the closed position with 20kV beam voltage and $3nA/cm^2$ current density.



(b) Discharges greater than 5 volts

Figure A10. - Cumulative number of discharges for thermal louvers in the closed position with 20kV beam voltage and $3 nA/cm^2$ current density.